The California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM)

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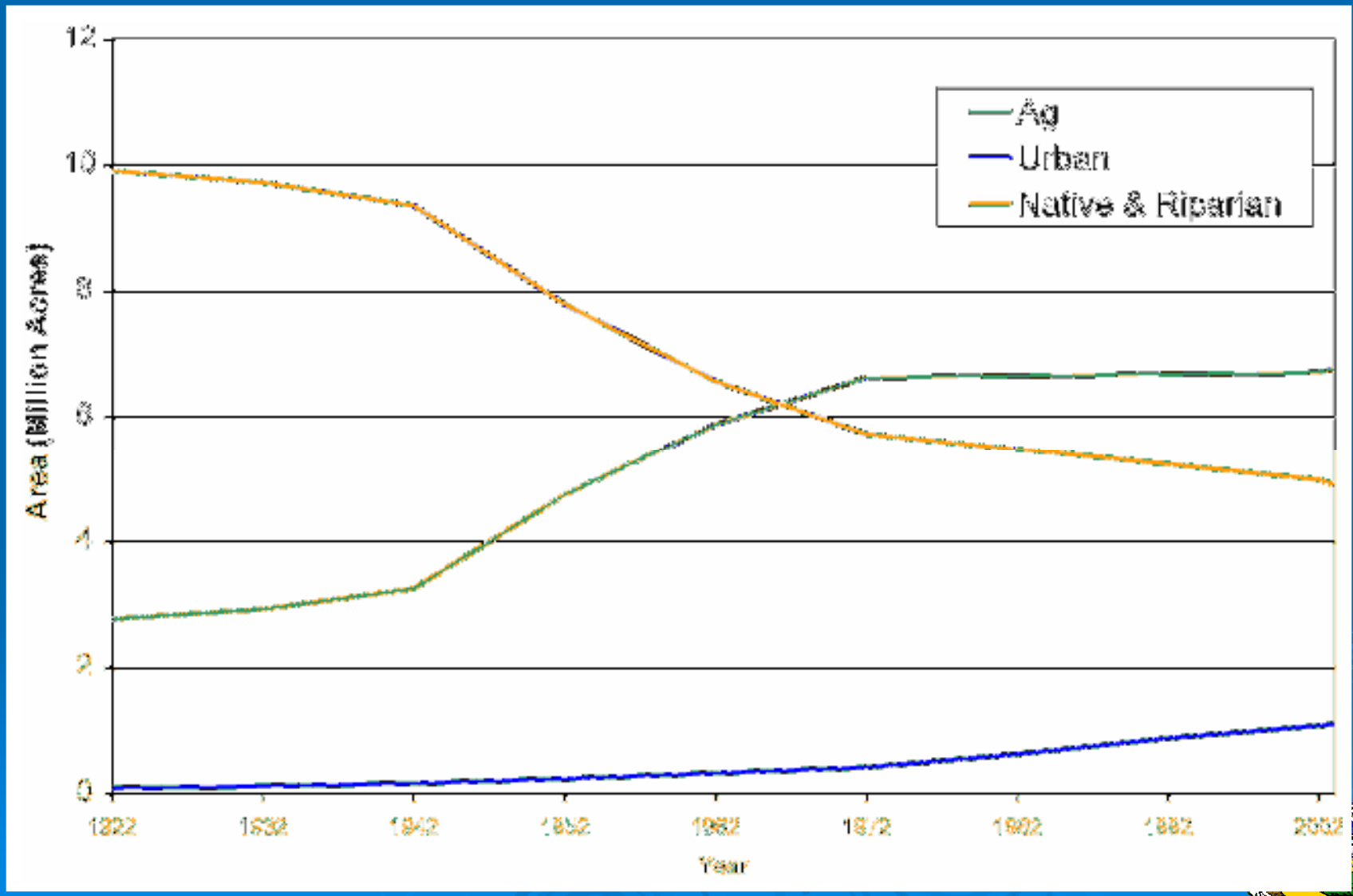
Outline

- Development of California's Central Valley
- Modeling Tools: IWFM and C2VSIM
- Overview of the C2VSIM model
- Model Calibration and Performance
- In-Lieu Conjunctive Use Scenario
- Climate Change Scenarios
- Summary

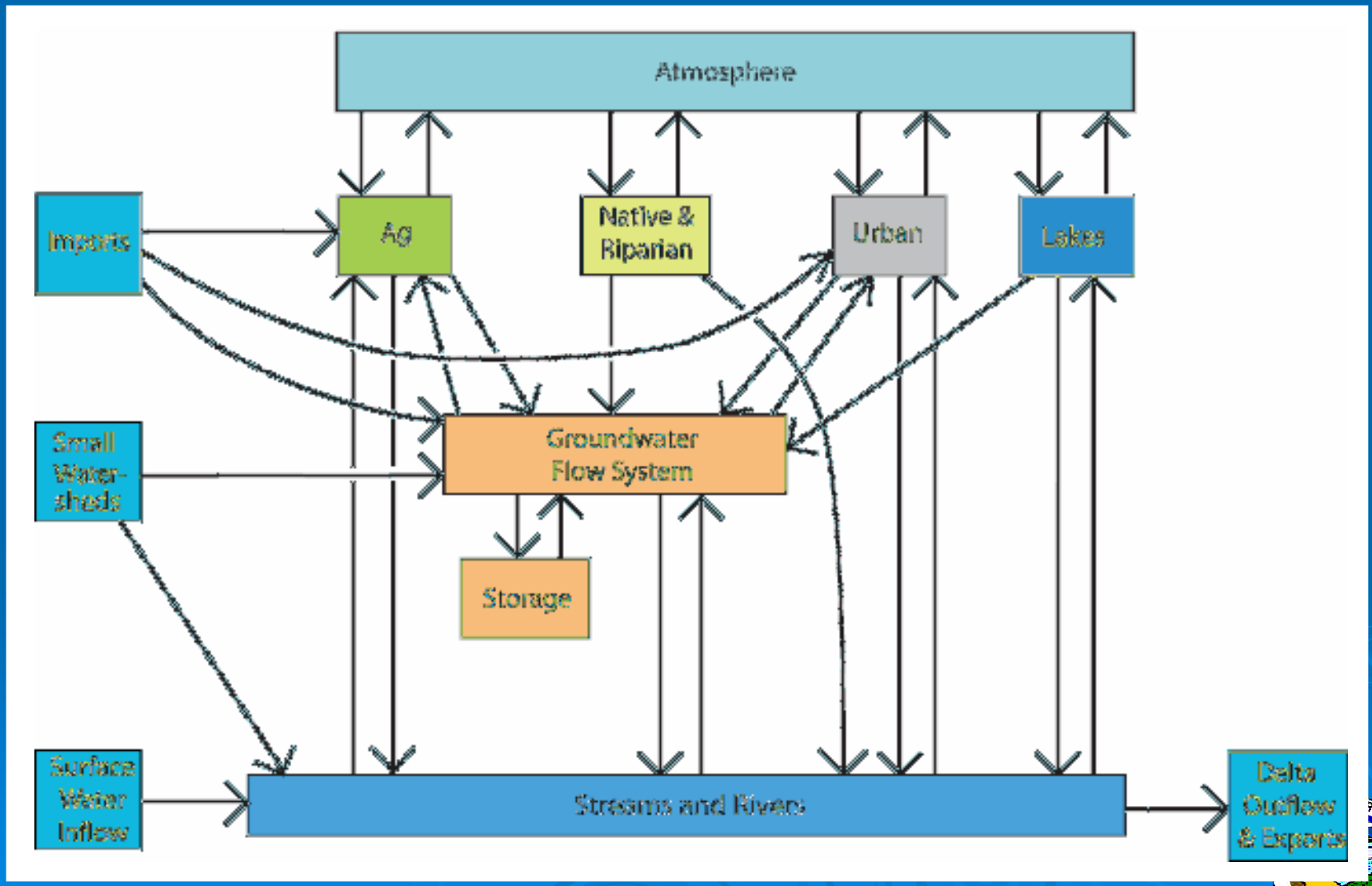
Historical Central Valley Land Use



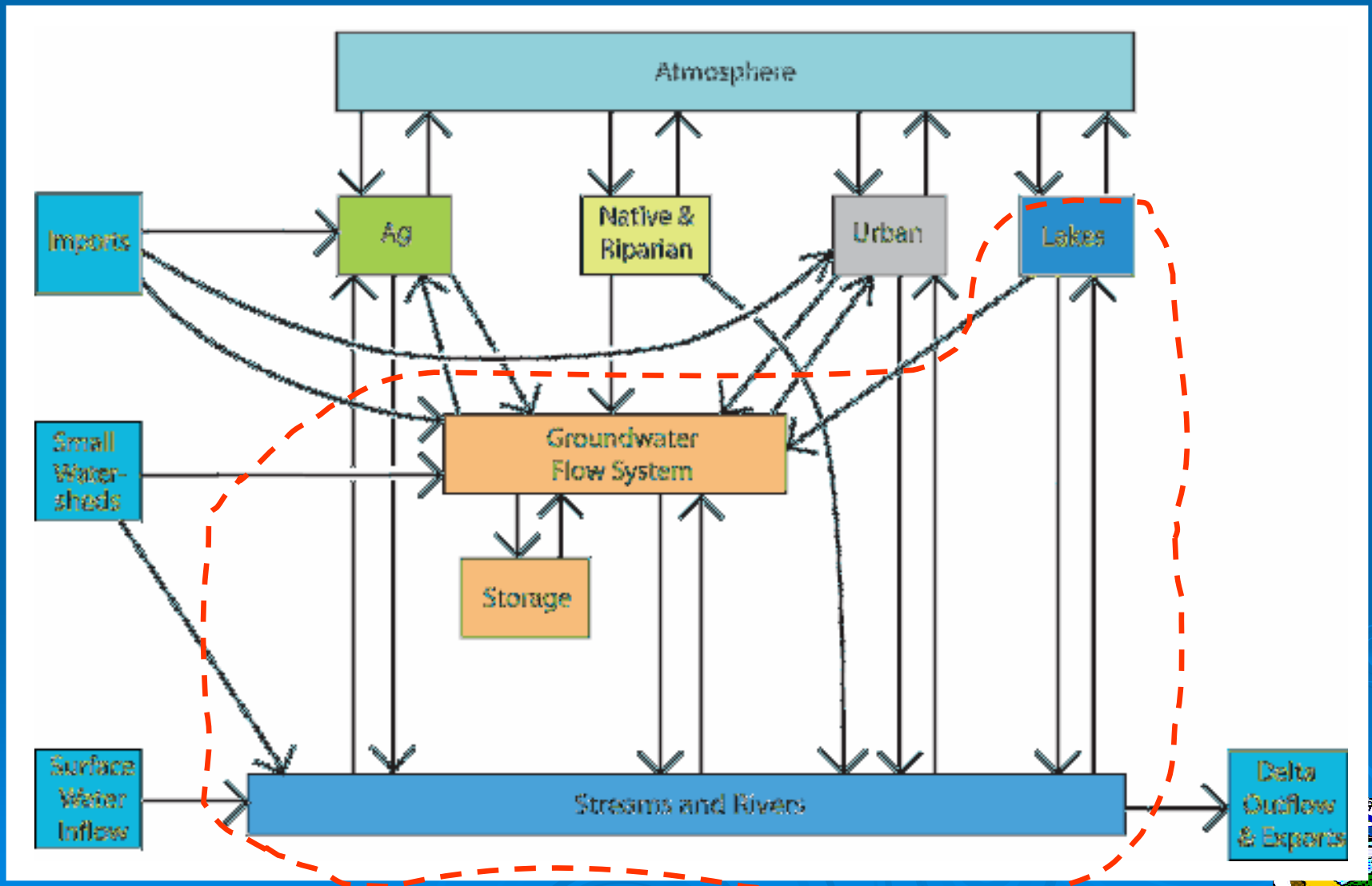
Central Valley Water Development

- 1850 - 1900 Introduction of agriculture
- 1890 - 1930 Local surface water projects
  - Ag expansion, re-purpose mining canals
- 1910 - 1970 Groundwater expansion
  - Ag follows electricity & population
- 1930 - 1980 Large surface water projects
- 1960 - 1990 Switch to surface water
  - Distribution system is completed
- 1980 - present Conjunctive use
  - Groundwater in dry years

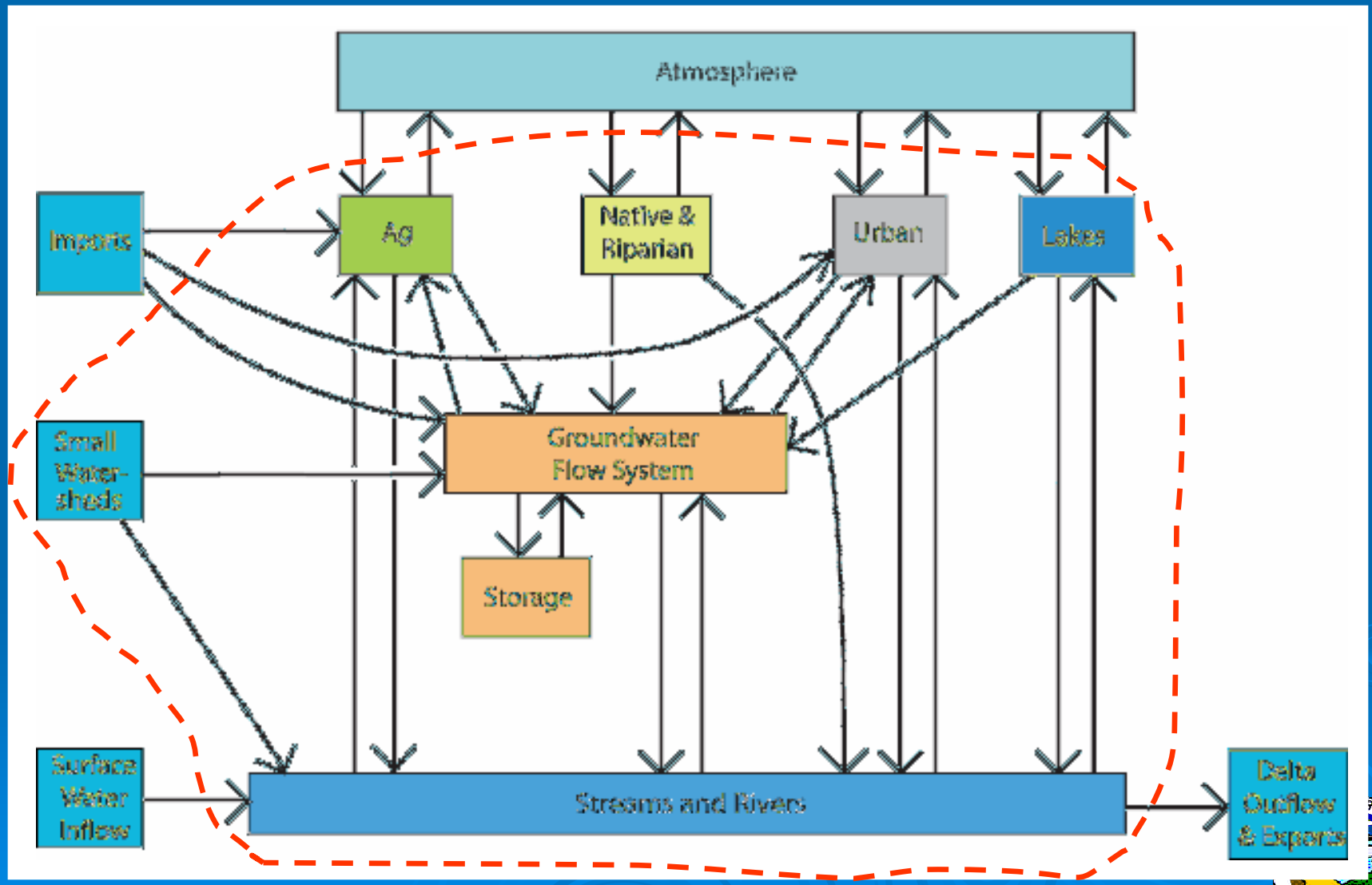
Components of the Hydrologic System



Groundwater Model Components



Integrated Model Components



IWFM - Integrated Water Flow Model

- Components
  - Groundwater Flow Process
    - Finite Element Grid
    - Saturated and unsaturated flow
  - Land Surface Process
    - Precipitation and Evapotranspiration
    - Land Type and Crop Acreages
    - Irrigation with Surface Water & Groundwater
  - Surface Water Processes
    - Streamflow routing
    - Lakes
    - Surface Water Diversions
  - Inflows from Ungaged Boundary Watersheds
- Outputs:
  - Water Budget Components
  - Estimated Groundwater Pumping

Groundwater Model Components

Component	Source
Parameters	calibration: WY 1973-2003
Initial conditions	water-level observations, 10/1921 or 10/1972
Boundary conditions	- Precipitation & evapotranspiration - Surface water inflows & diversions
Recharge & Pumping calc	- Land use & crop acreages - Crop coefficients - Soil type, SCS curve number - Pump locations (well database)

C2VSIM Model Grid

Finite Element Grid

- 3 layers
- 1393 nodes
- 1392 elements

Surface Water System

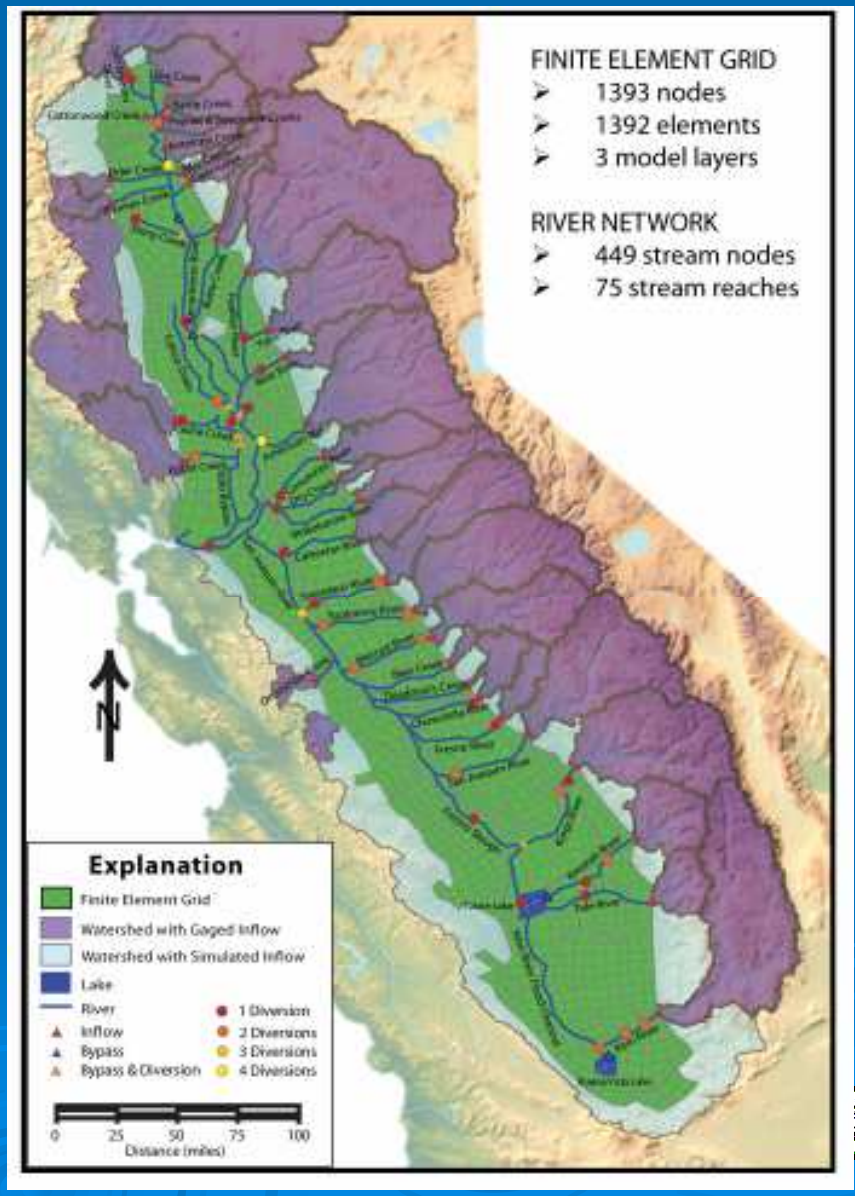
- 75 river reaches
- 2 lakes
- 97 surface water diversion points
- 6 bypasses

Land Use Process

- 21 subregions
- 4 Land Use Types
  - Agriculture
  - Urban
  - Native
  - Riparian

Simulation periods

- 10/1921-9/2003
- 10/1972-9/2003 (<4 min)



C2VSIM Subregions

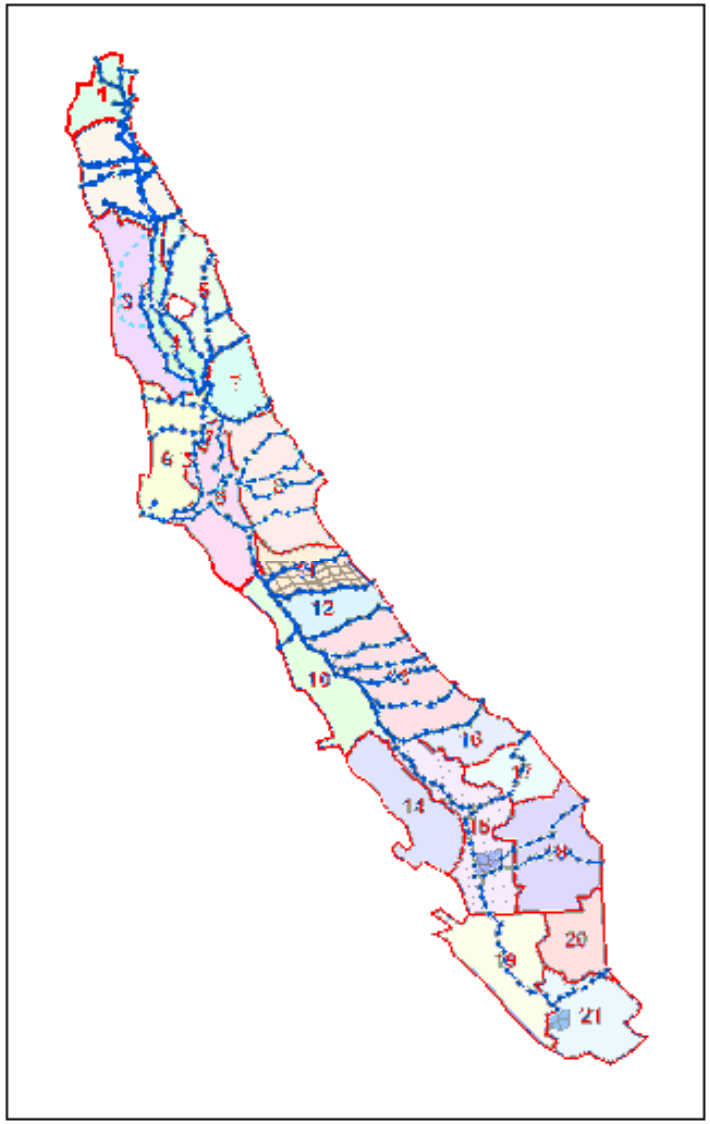
Water Budget Calculations

- Land use by element
- Aggregate to subregion

By land use in subregion:

- Calculate water demands
- Apply soil moisture
- Apply surface water diversions
- Apply/estimate groundwater pumping
- Calculate soil moisture, recharge, return flows

Allocate to elements by land use areas



Changes Since Initial Calibration

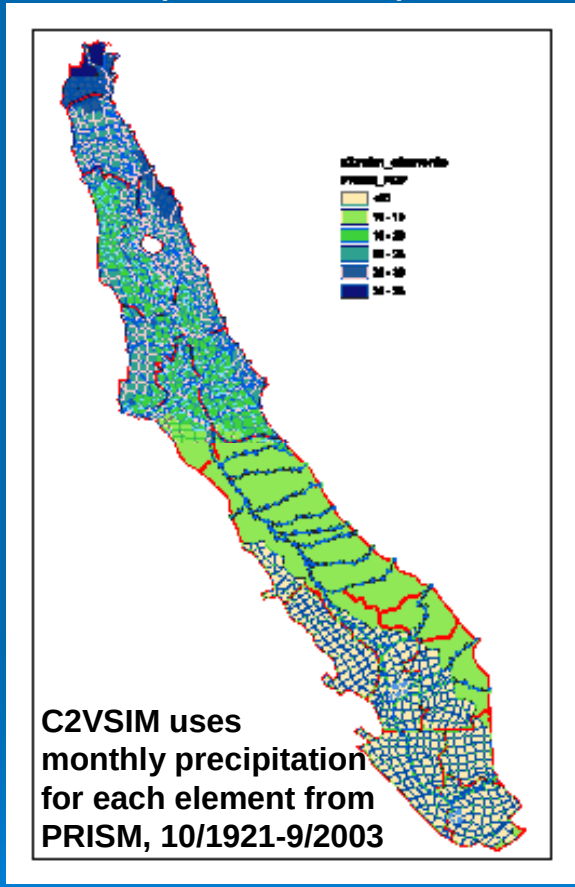
R305 of July 2006 to R323 of May 2008

- Model-wide changes
  - IWFM 2.4.1 to IWFM 3.0 (time tracking)
  - Elemental monthly precipitation from PRISM
  - Pumping distribution matches well completion database
  - Map-based small-stream watersheds with SSURGO parameters
- Sacramento-San Joaquin Delta
  - Constant-head groundwater nodes to variable-head nodes
  - Extended river system to Carquinez Straits
  - Variable-stage river node rating curves
- Tulare Basin
  - Removed external flow of lake water
  - Added Kern River Flood Channel, Tulare Lake outflow

Recent changes to the Tulare Basin hydrology will require some additional calibration of parameters in Kern County (SR 19-21)

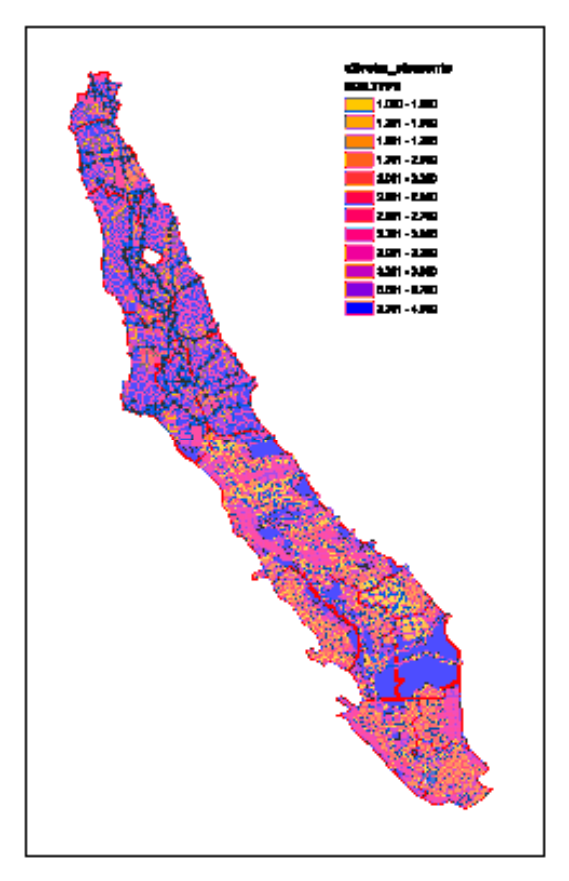
Examples of Elemental Data

Annual Average Precipitation (1971-2000)

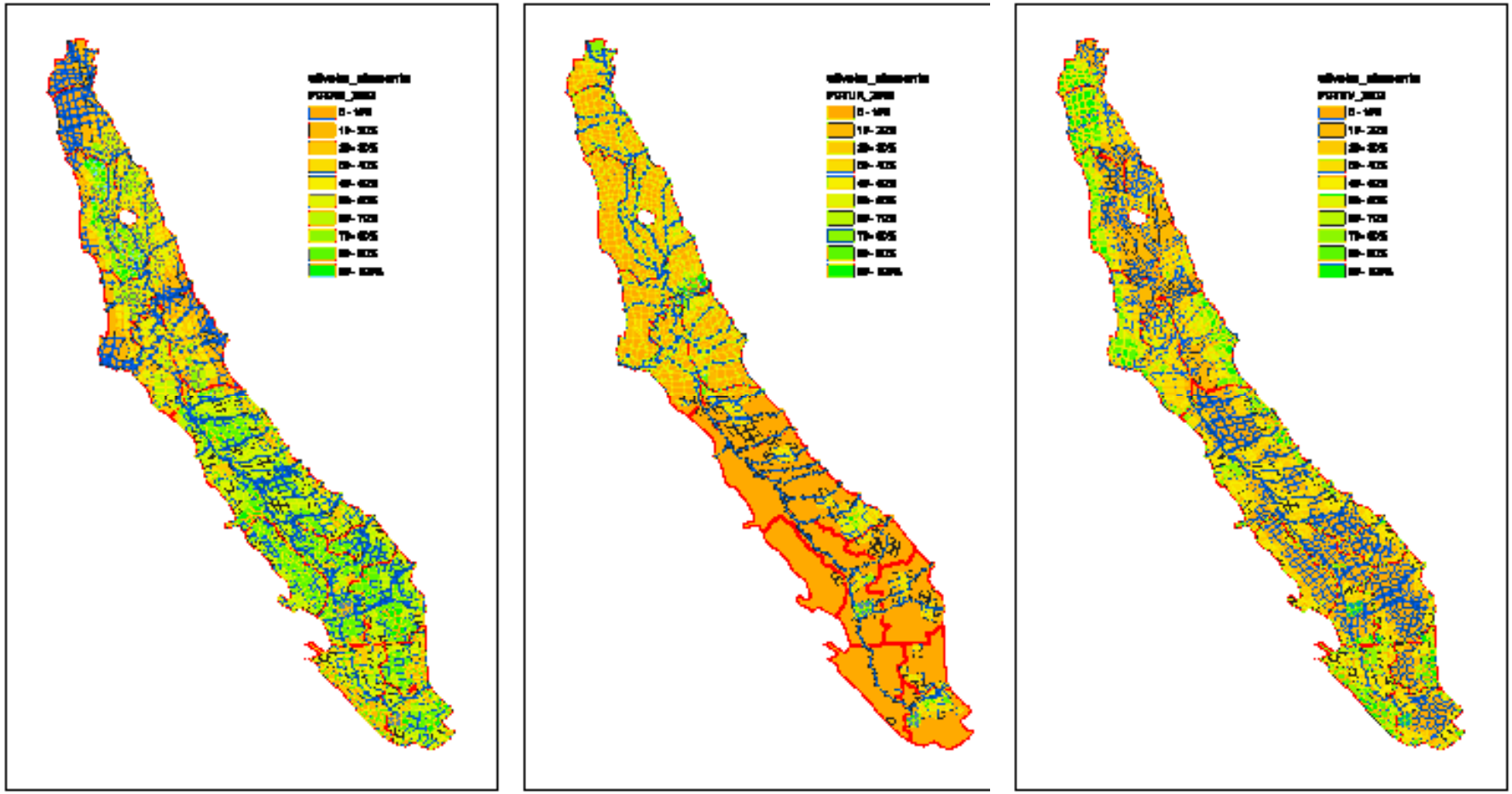


C2VSIM uses monthly precipitation for each element from PRISM, 10/1921-9/2003

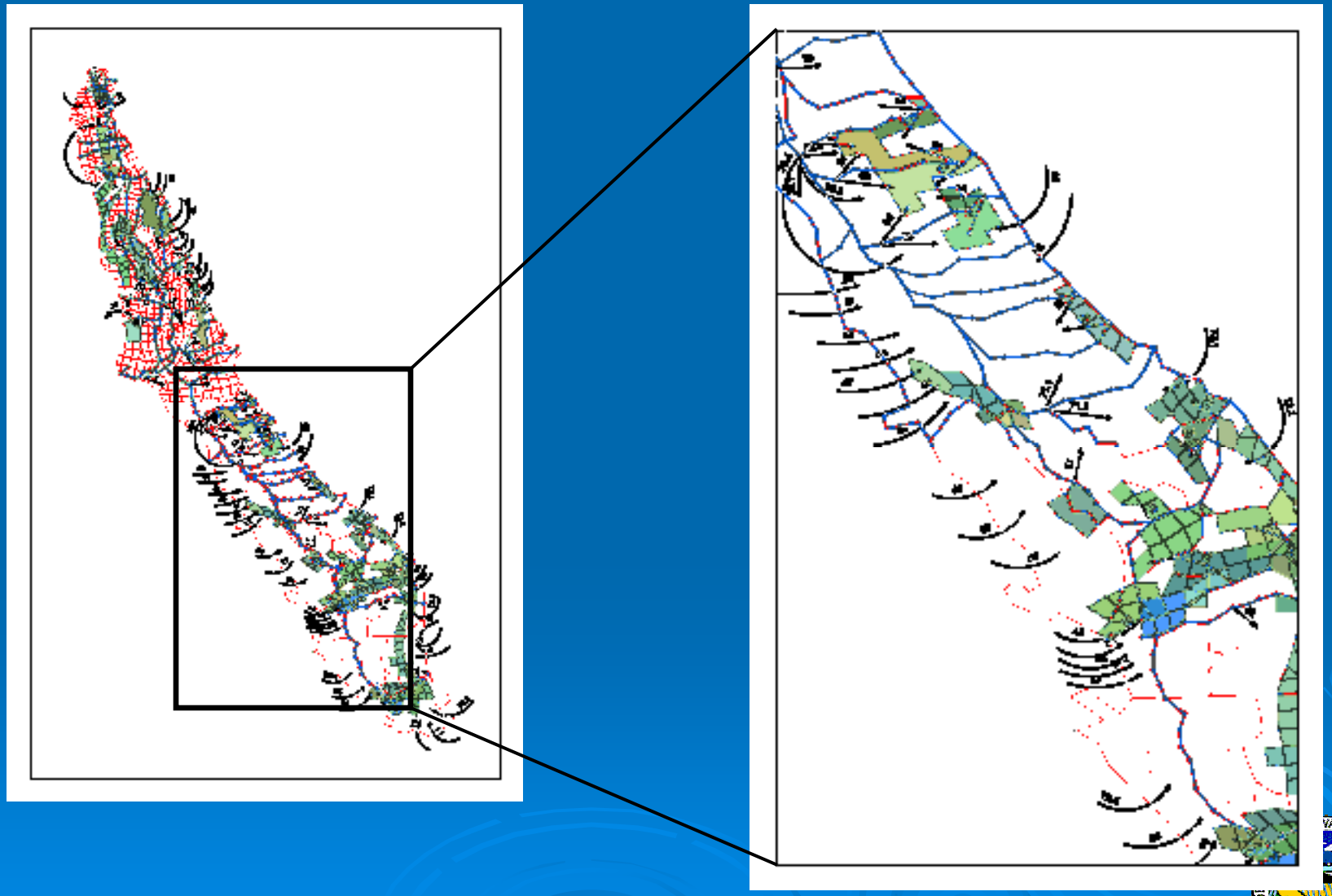
Hydrologic Soil Group



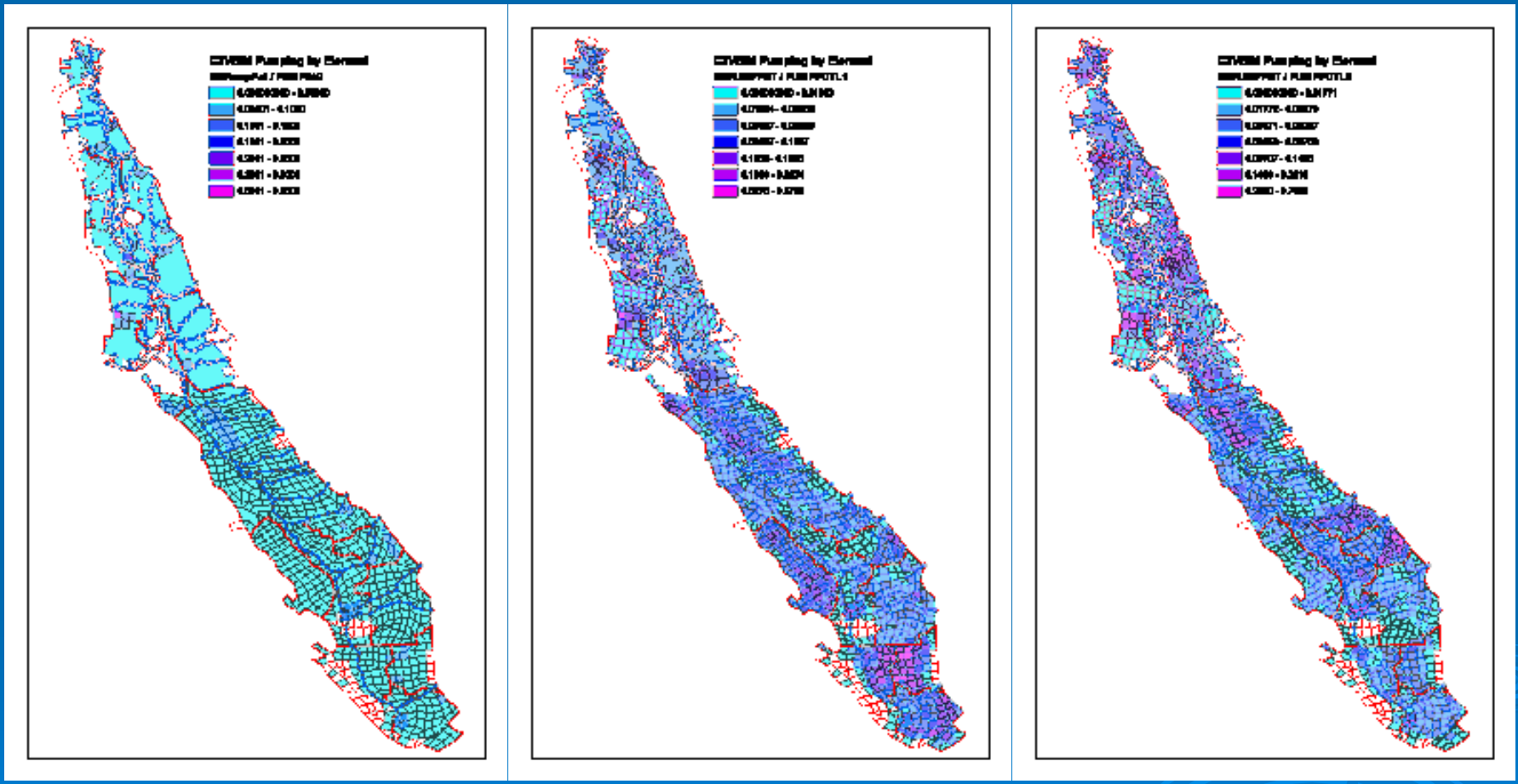
C2VSIM Land Use 2003



C2VSIM Diversions



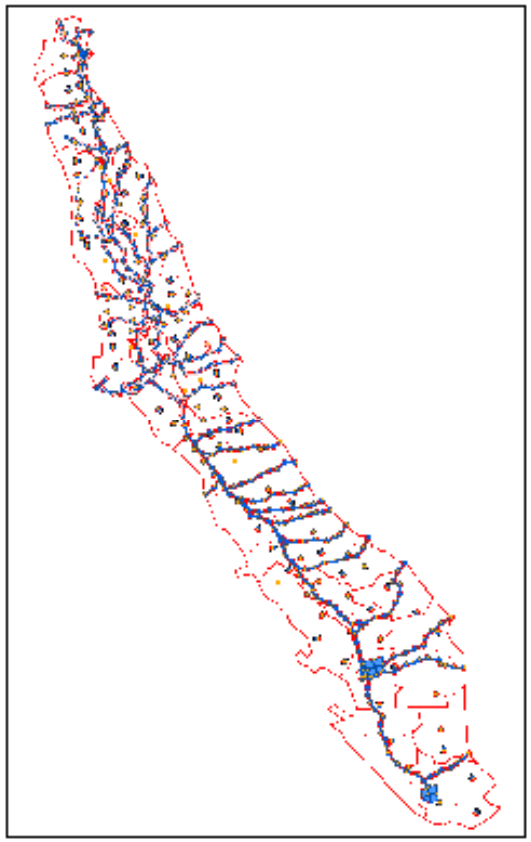
C2VSIM Groundwater Pumping



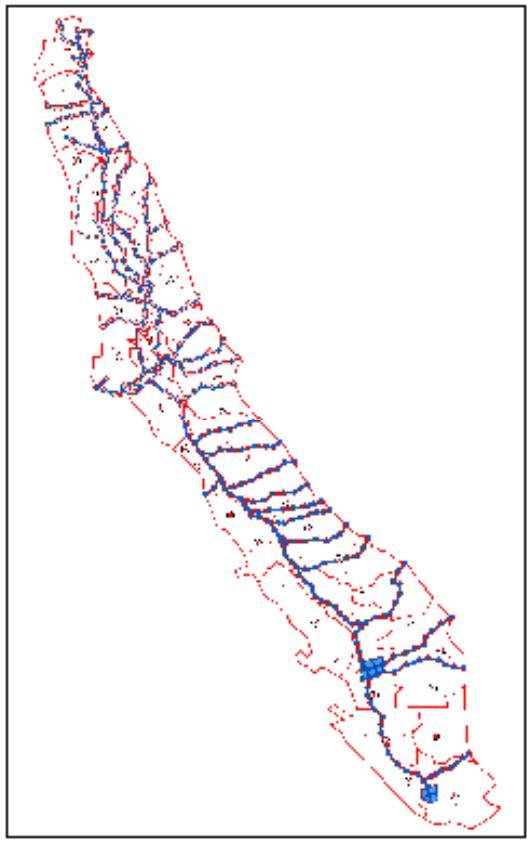
C2VSIM Initial Calibration

Pilot Points

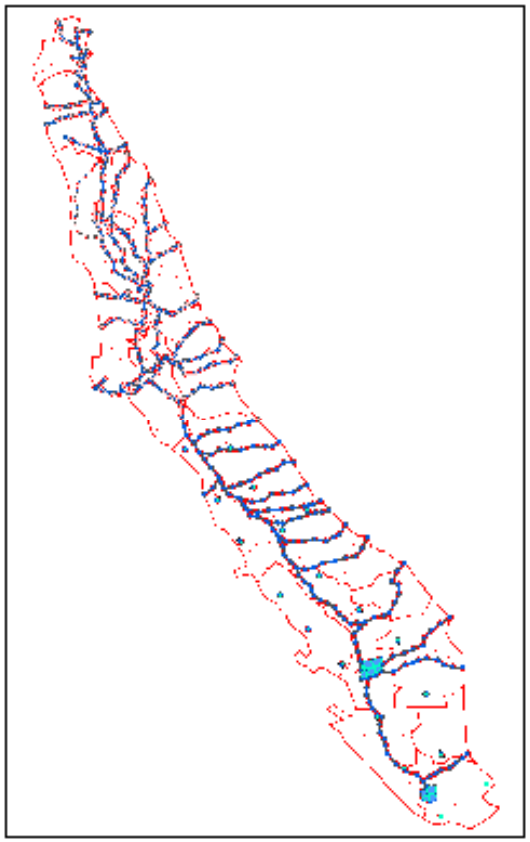
140 in layers 1 & 2



39 in layer 3



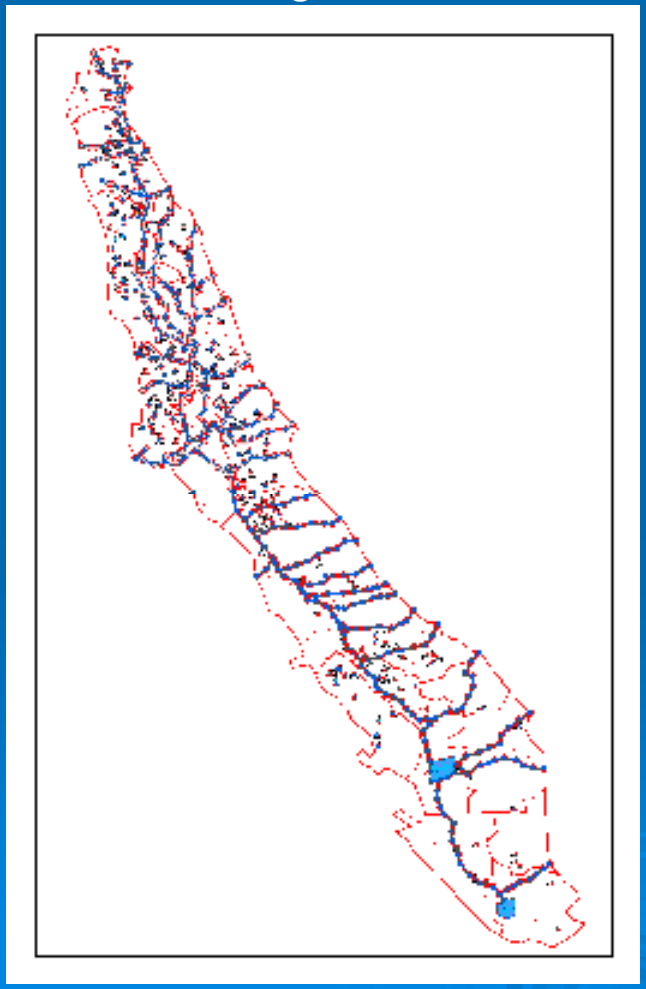
19 for Corcoran Clay



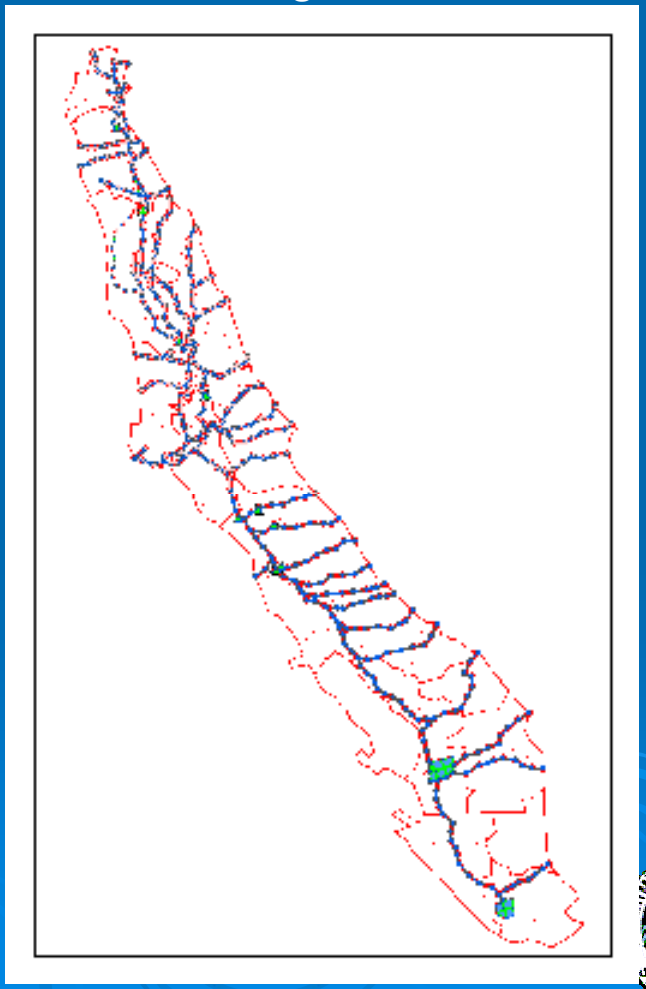
C2VSIM Initial Calibration

Observations

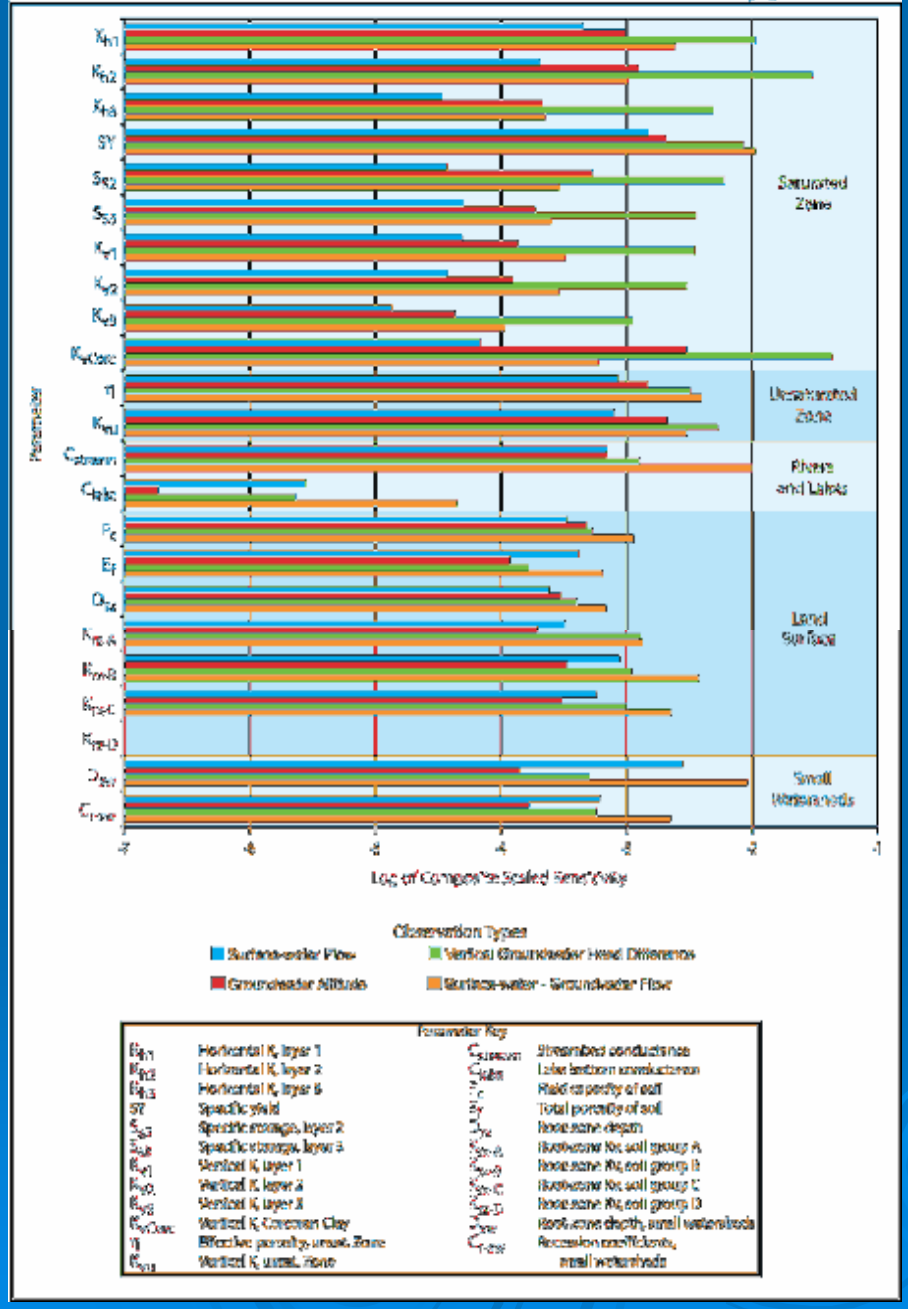
221 groundwater head
9 head gradient



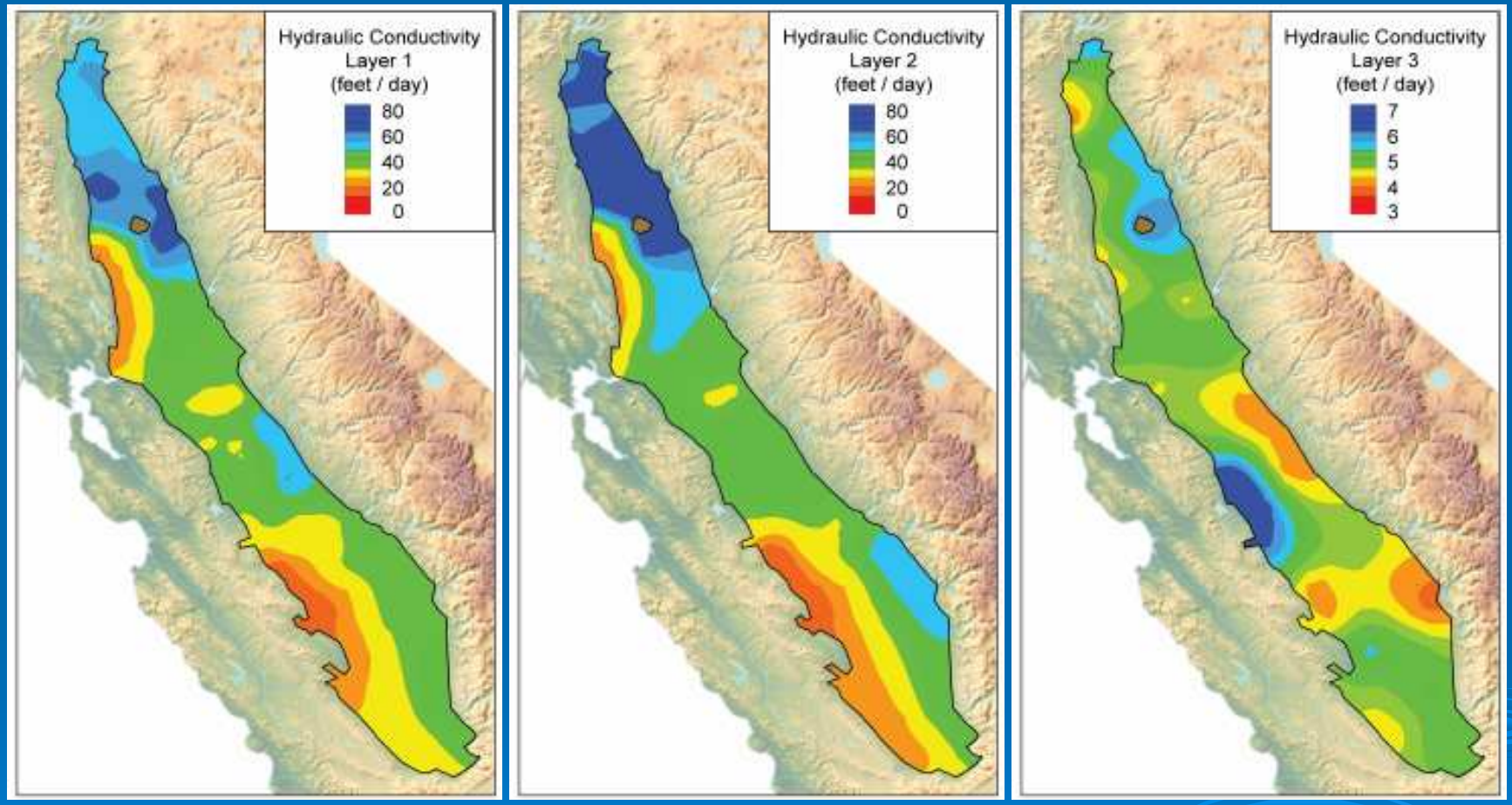
9 river flow
34 stream-groundwater



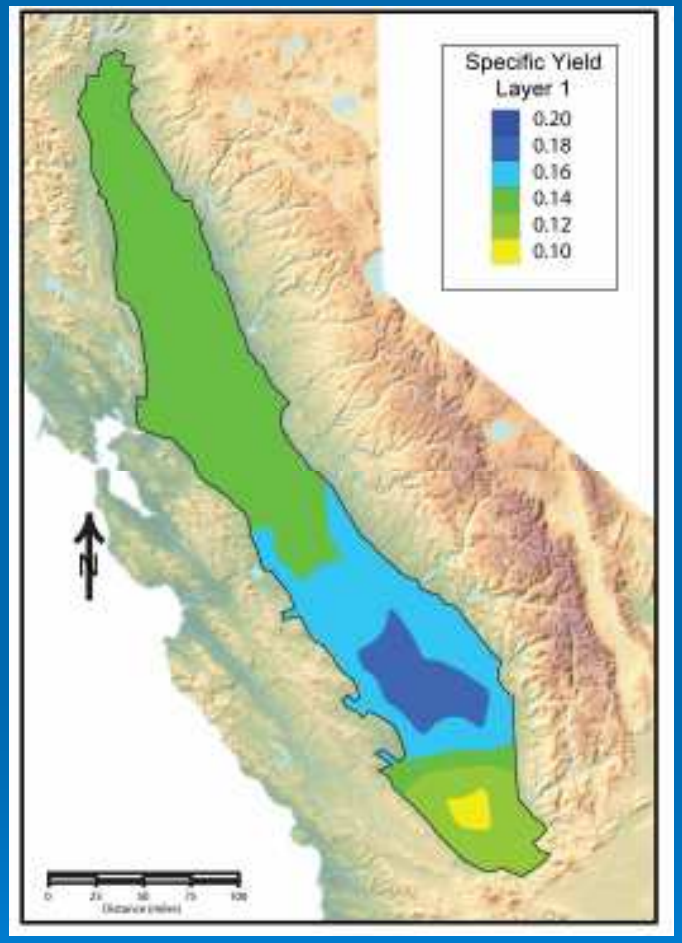
Parameter Sensitivities vs. Observation Types

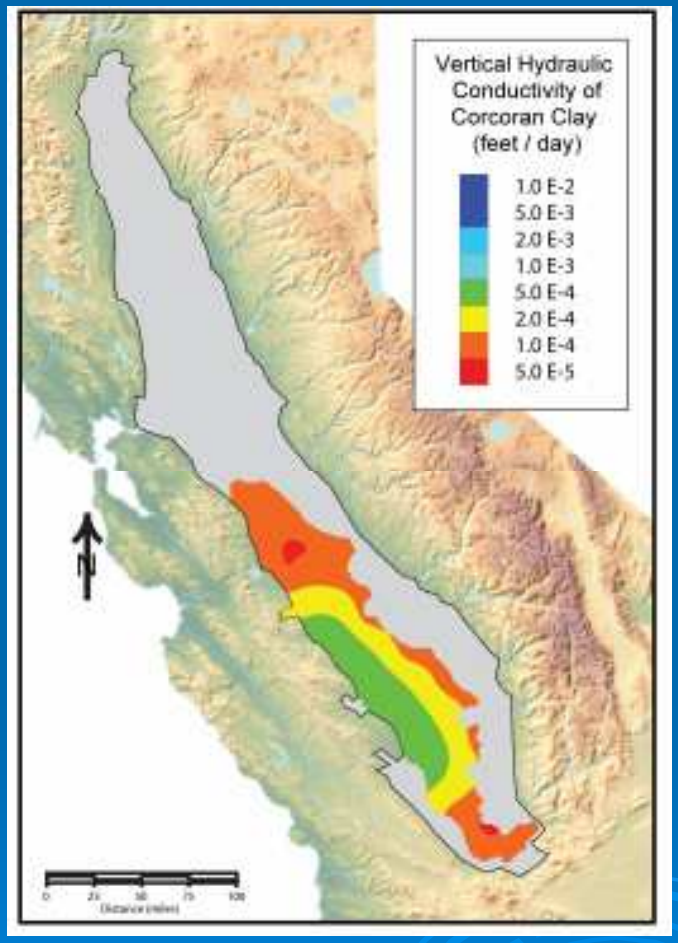


Hydraulic Conductivity

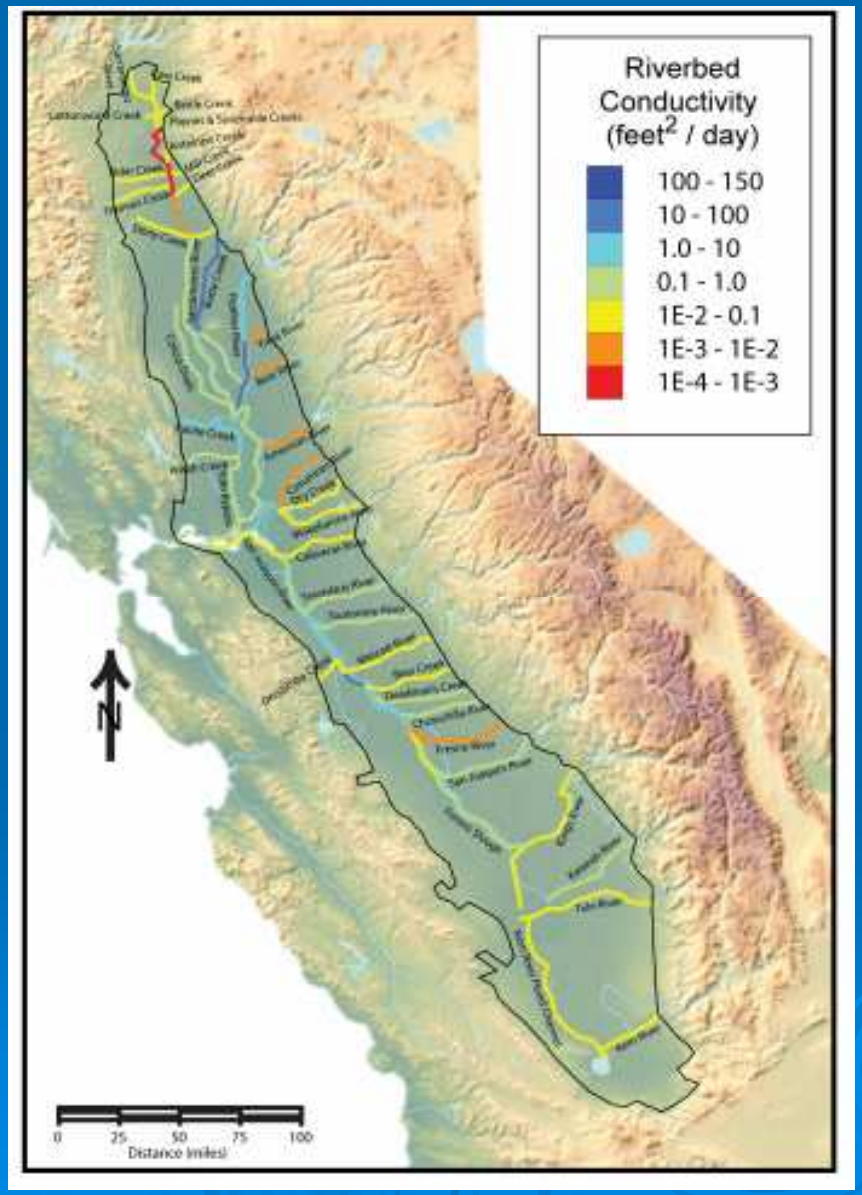


Specific Yield & Kv of Corcoran Clay

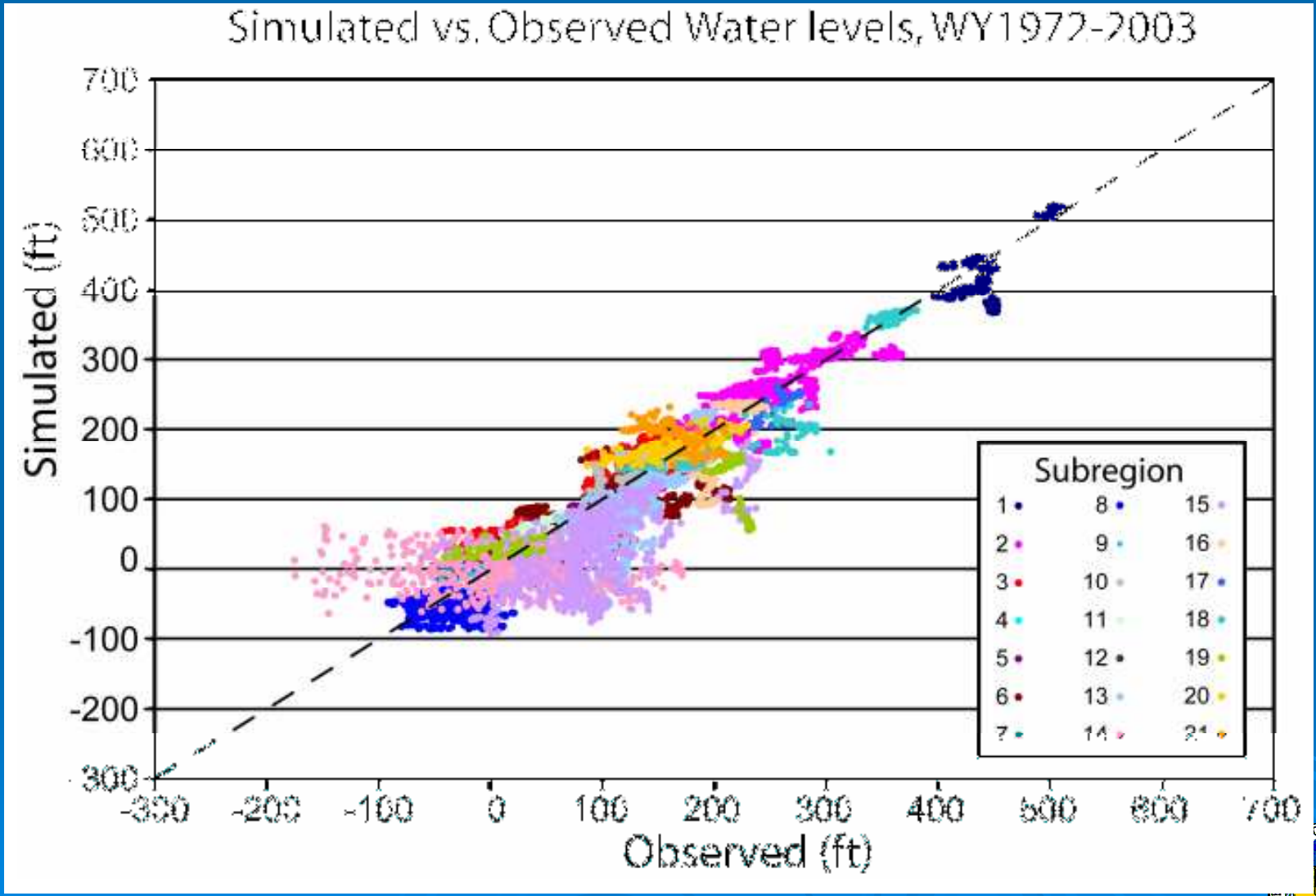




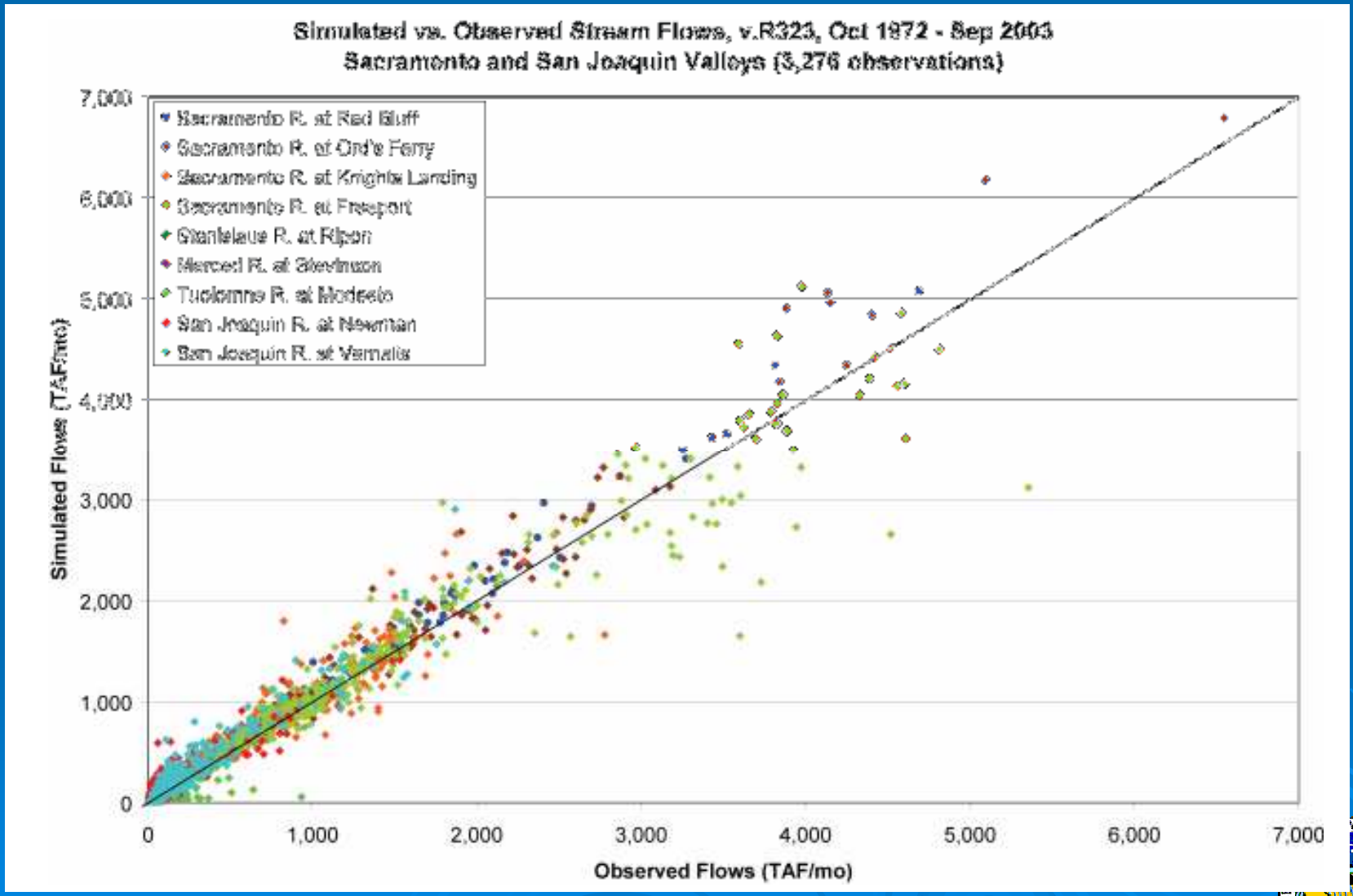
Streambed Conductance



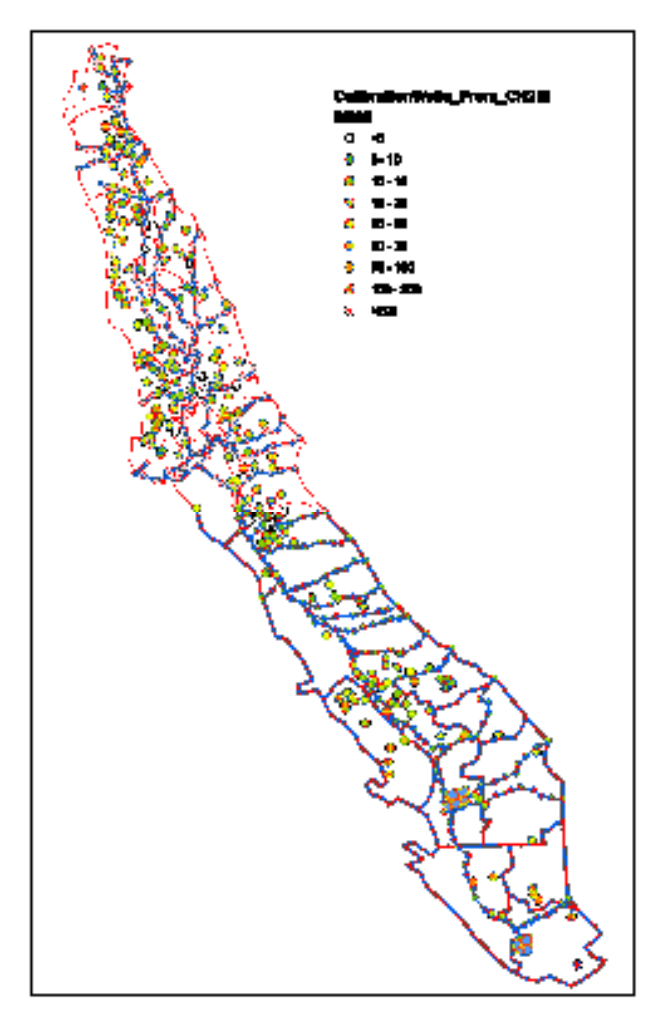
C2VSIM Performance – Heads
R305 – Initial Calibration

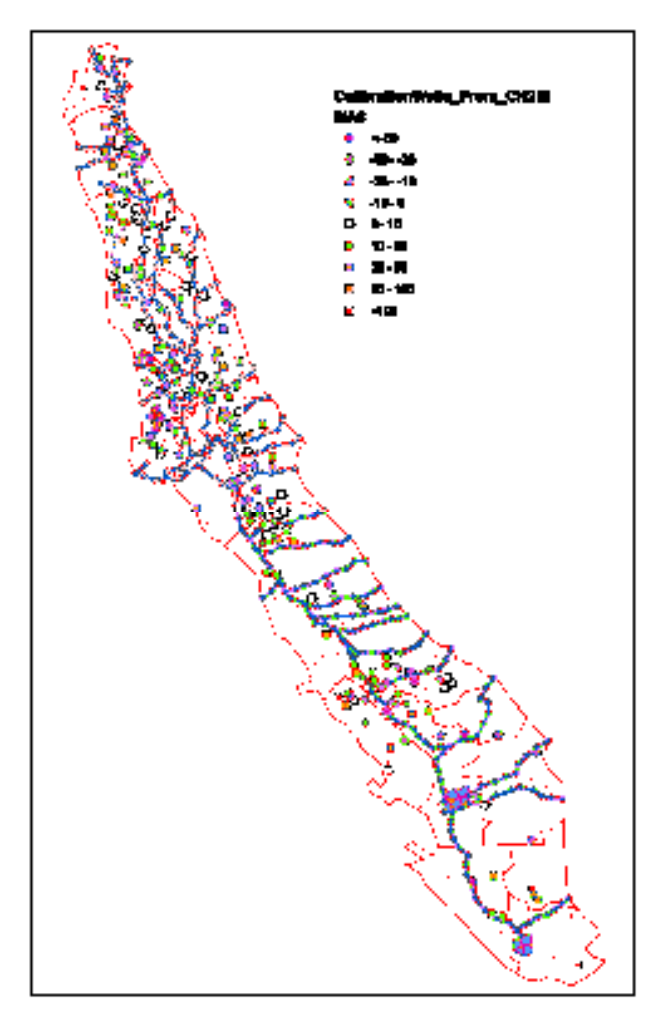


C2VSIM Performance - Flows

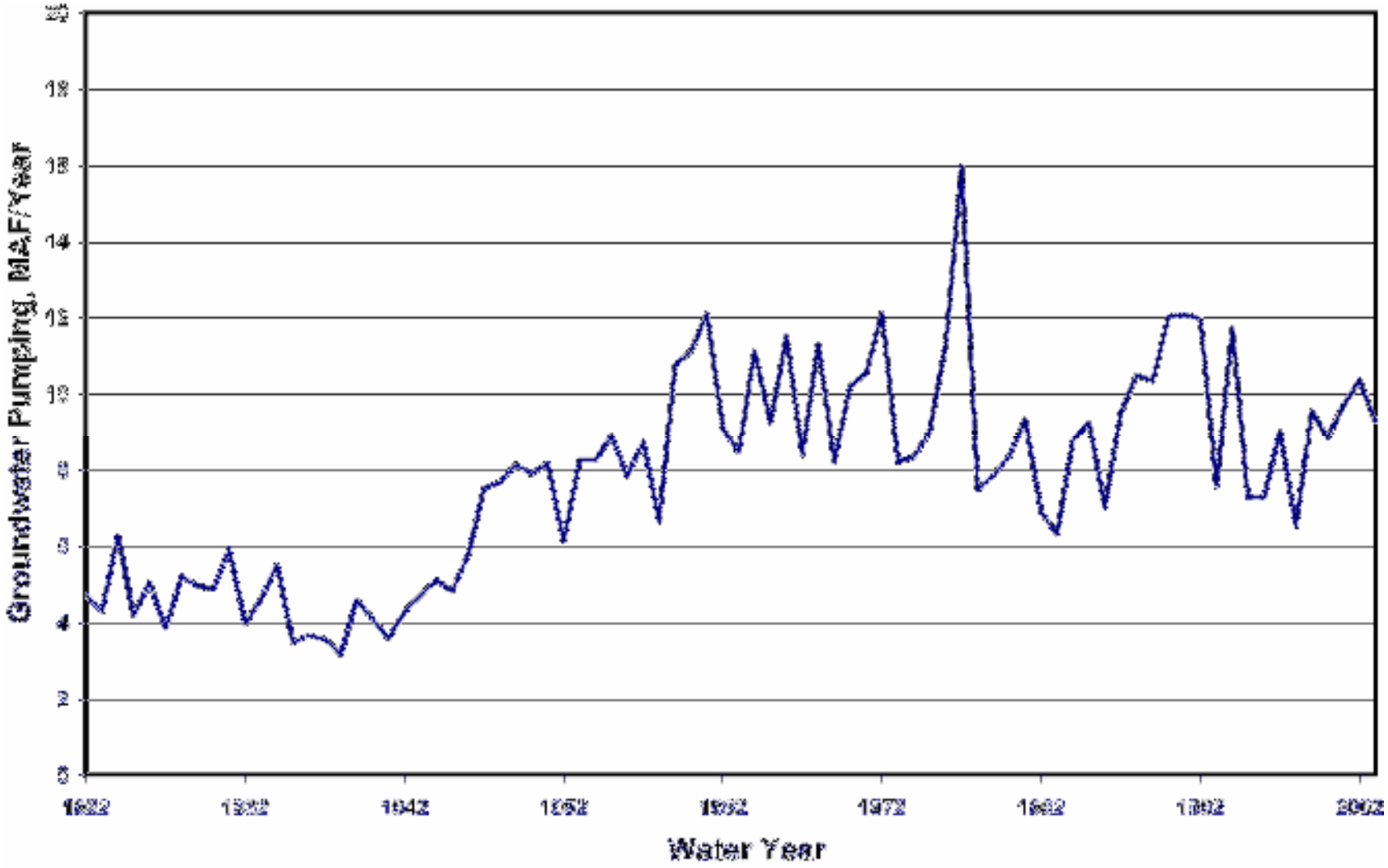


C2VSIM Performance – RMSE and BIAS

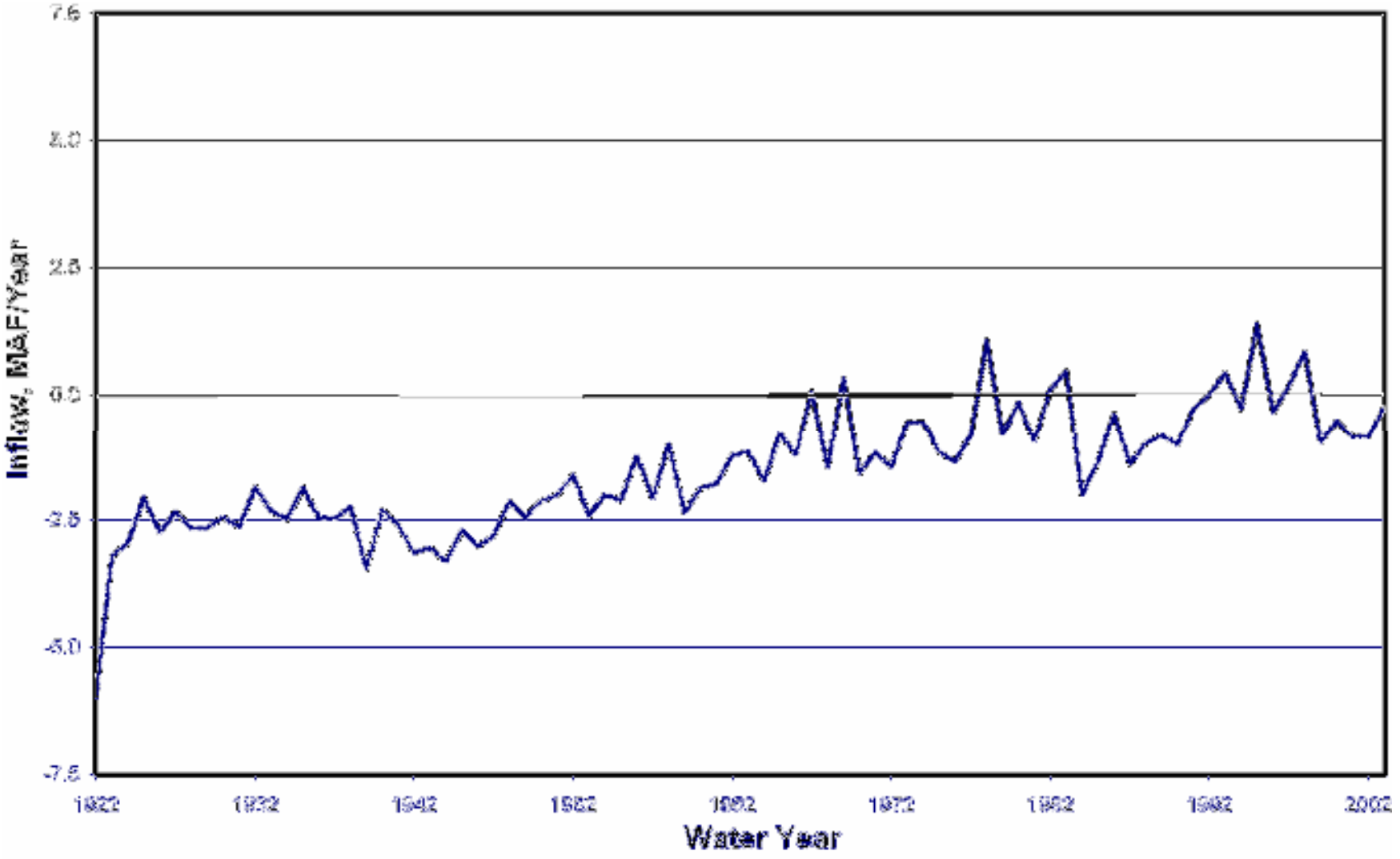




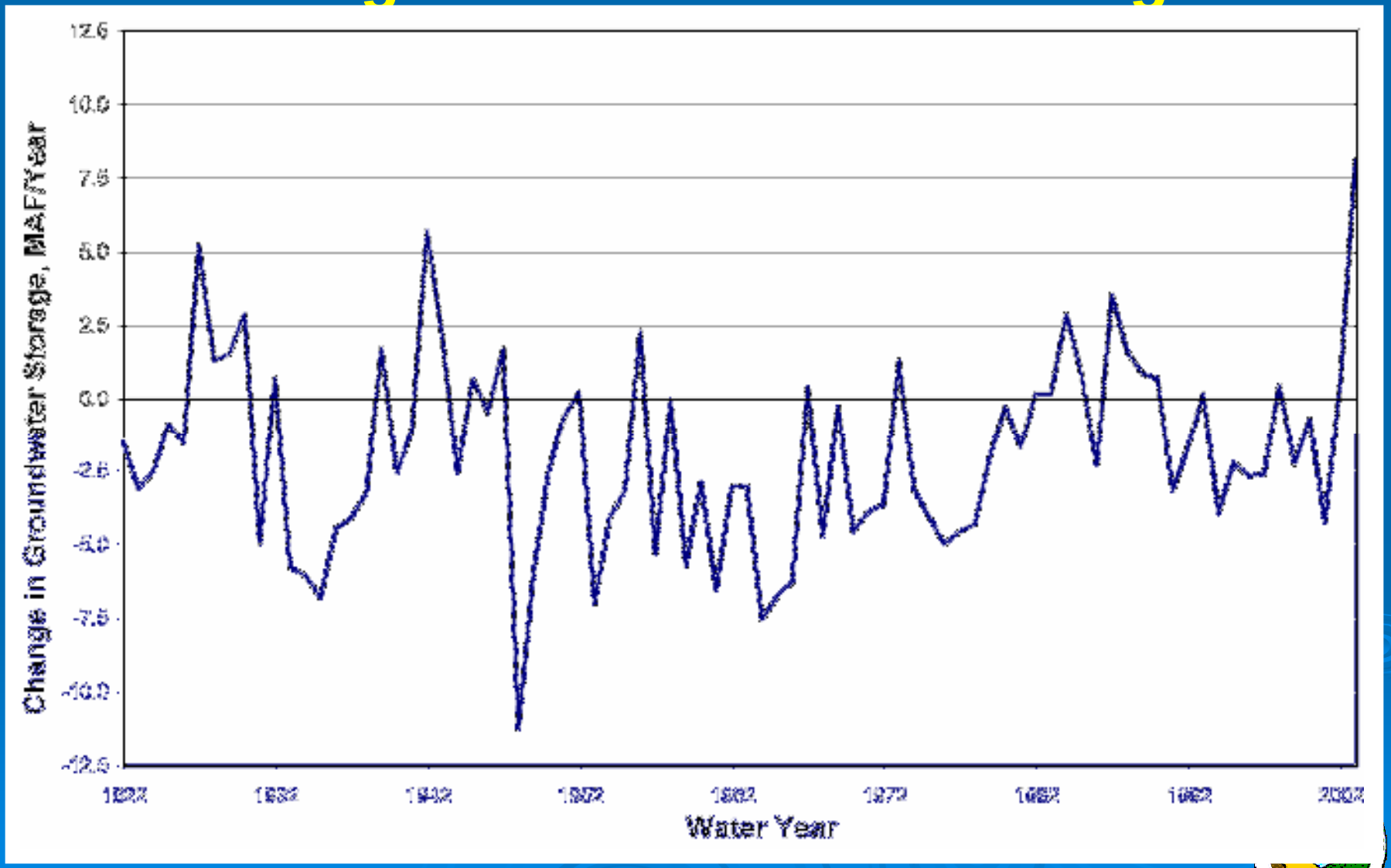
Groundwater Pumping



Stream-Aquifer Interaction



Change in Groundwater Storage



Simulated Water Budget Components

Average Annual Rates for Water Years 1975-2003

	Storage	Stream Leakage	Subsidence	Pumpage	Recharge	Interbasin Flows
Sacramento Valley	200,174	-350,859	51	-2,089,333	2,225,060	14,908
Delta	-82,464	-30,188	-105	-204,022	430,915	-114,136
Eastside Streams	139,029	109,888	50	-771,925	308,327	214,631
San Joaquin Basin	150,969	-499,100	798	-1,414,172	1,935,691	-174,196
Tulare Basin	-2,109,300	-485,561	-9,533	-3,807,986	6,350,697	58,794
Model Area	-1,701,592	-1,255,821	-8,739	-8,287,438	11,250,690	0

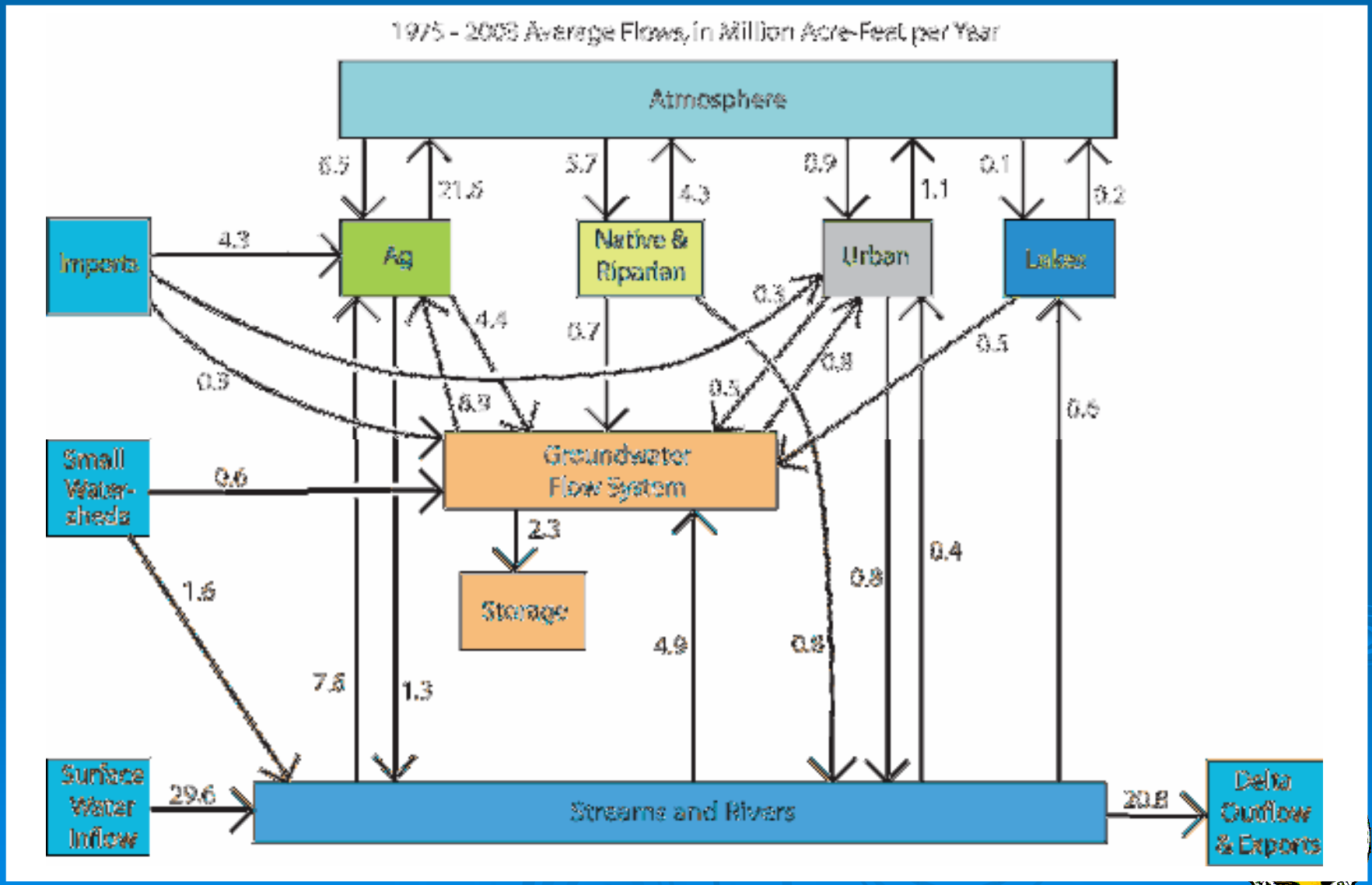
Simulated Water Budget Components

Average Annual Rates for Water Years 1975-2003

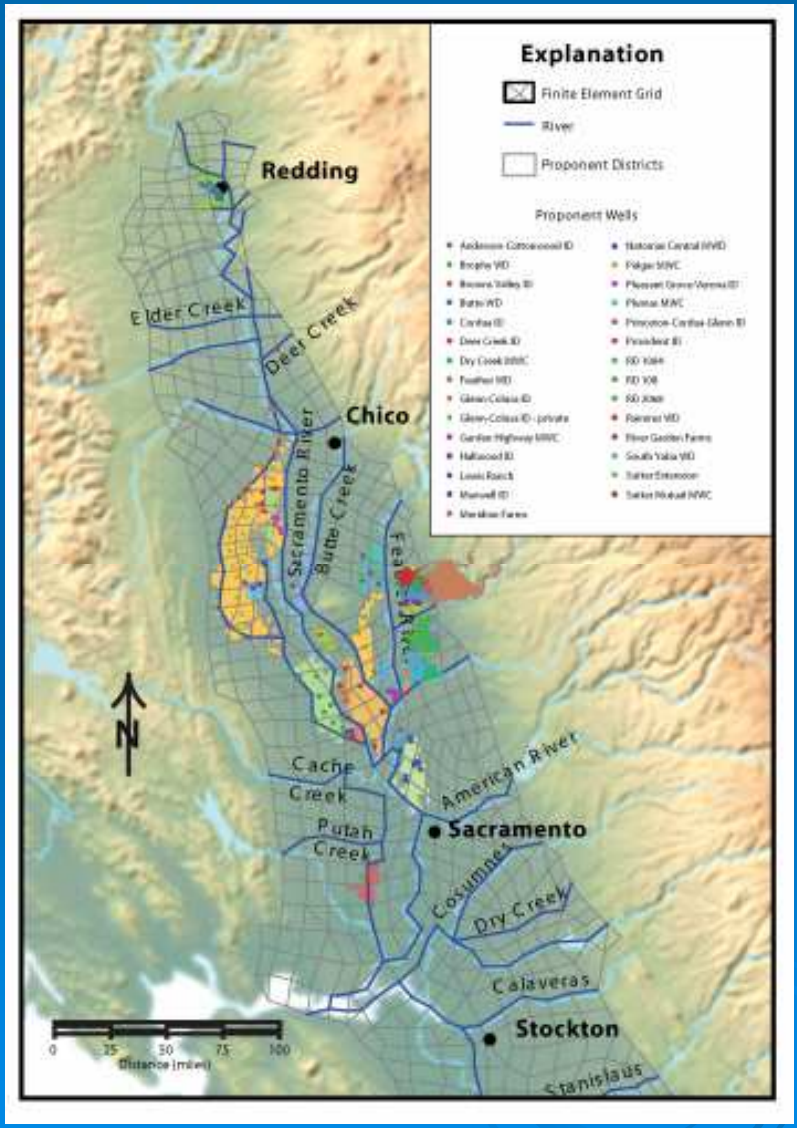
	Surface Water Inflows*	Surface Water Outflows*	Precipitation	Actual Evapo-transpiration
Sacramento Valley	19,955,538	17,759,801	6,849,346	8,472,276
Delta	31,005,209	25,564,486	926,265	1,533,207
Eastside Streams	1,307,325	1,443,871	1,405,900	1,683,961
San Joaquin Basin	5,820,154	4,535,437	2,521,049	5,544,759
Tulare Basin	3,220,309	1,179,001	3,584,871	10,596,423
Model Area	30,923,480	26,783,332	15,287,431	27,830,625

* Surface water inflows and outflows do not add up across hydrologic regions

Water Budget



Analyze a Conjunctive Use Scenario (In-Lieu Pumping)



Proposed Participants

- 29 Districts
- 293 wells
- 187,633 AF/year

Operate “non-wet” years

- 1973 1 yr
- 1976-81 6 yrs
- 1985 1 yr
- 1987-94 8 yrs
- 2000-03 4 yrs

Sacramento River Index

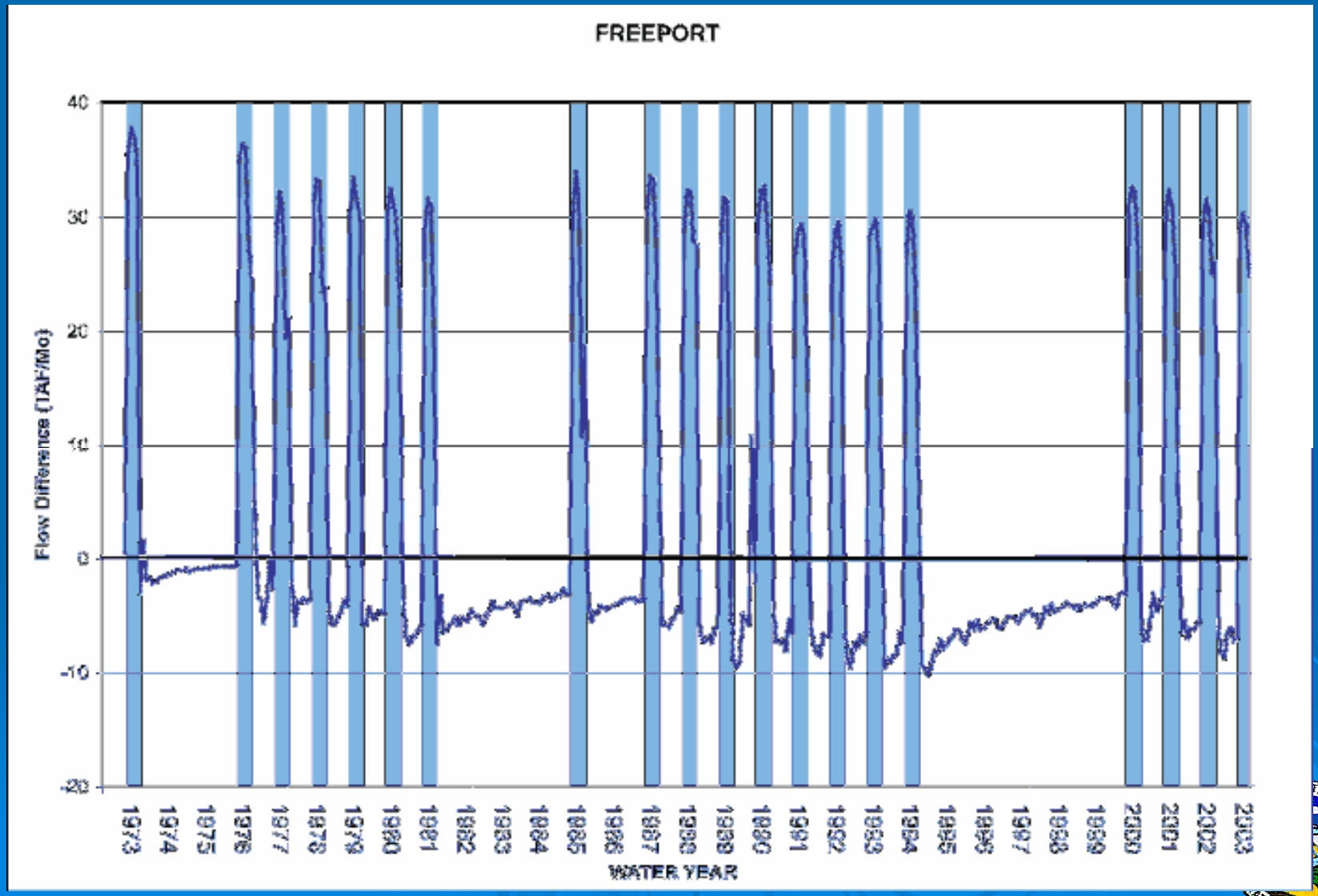
Water Year	WY Index		Project
	Index	Yr-type	Operation
1972	7.29	BN	-
1973	8.58	AN	ON
1974	12.99	W	OFF
1975	9.35	W	OFF
1976	5.29	C	ON
1977	3.11	C	ON
1978	8.65	AN	ON
1979	6.67	BN	ON
1980	9.04	AN	ON
1981	6.21	D	ON
1982	12.76	W	OFF
1983	15.29	W	OFF
1984	10	W	OFF
1985	6.47	D	ON
1986	9.96	W	OFF
1987	5.86	D	ON

Water Year	WY Index		Project
	Index	Yr-type	Operation
1988	4.65	C	ON
1989	6.13	D	ON
1990	4.81	C	ON
1991	4.21	C	ON
1992	4.06	C	ON
1993	8.54	AN	ON
1994	5.02	C	ON
1995	12.89	W	OFF
1996	10.26	W	OFF
1997	10.82	W	OFF
1998	13.31	W	OFF
1999	9.8	W	OFF
2000	8.94	AN	ON
2001	5.76	D	ON
2002	6.35	D	ON
2003	8.21	AN	ON

C2VSIM Simulation of a Proposed In-Lieu Groundwater Pumping Program

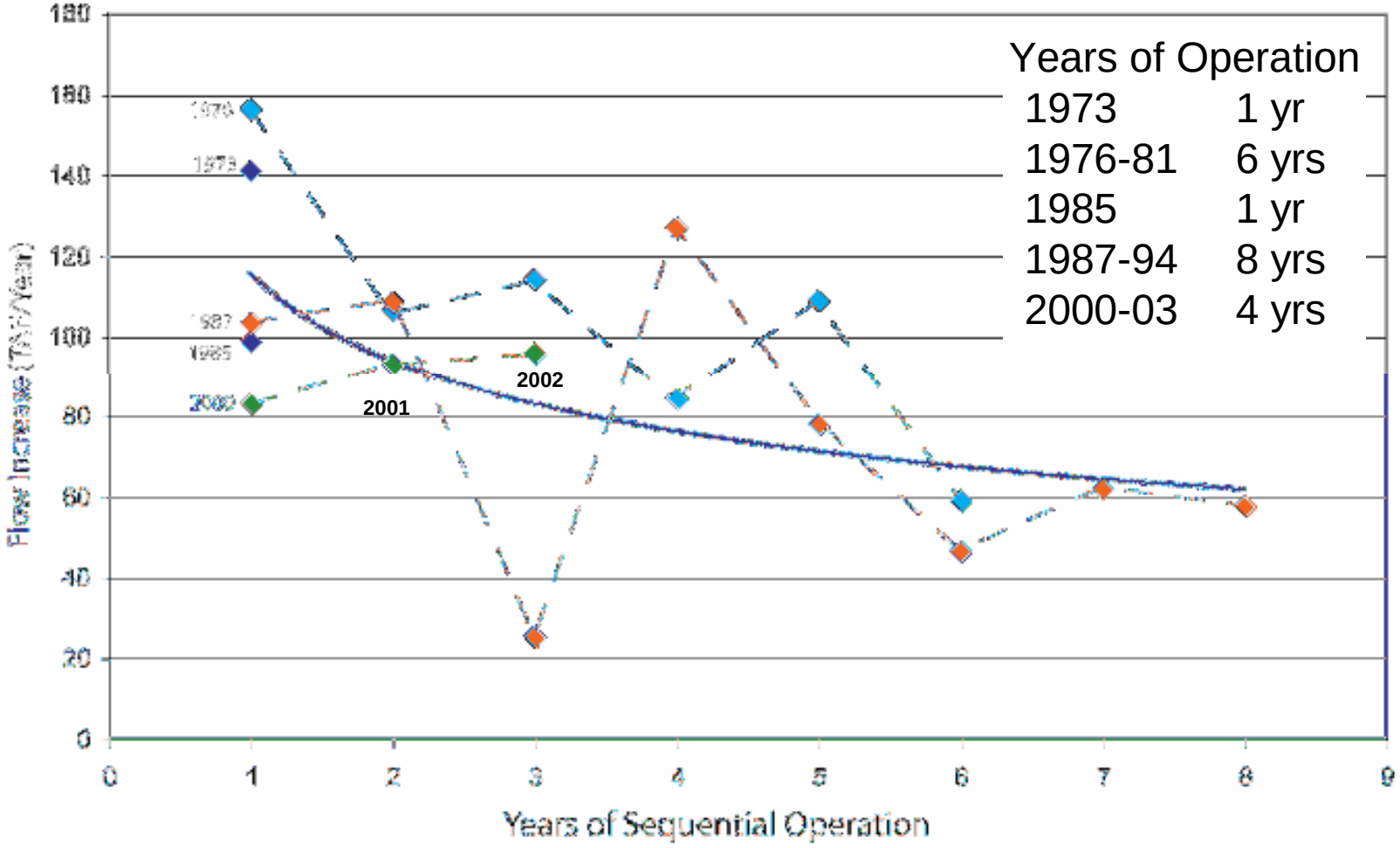
- Identify individual wells and pumping rates
- Prepare IWFM input files
  - October 1972 through September 2003
  - Pumps on in non-wet years
- C2VSIM runs
  1. Turn on groundwater adjustment
  2. Turn on surface water adjustment
  3. Turn on SVWMP wells & reduce diversions in non-wet years (Sacramento River Index)

Change in River Flow



Summer Flow Increase at Freeport vs. Years of Sequential Operation

Scenario vs. Base Case, Sacramento River at Freeport



C2VSIM Simulation of Reduced Surface Water Availability Scenarios

Joint LBNL-DWR Project

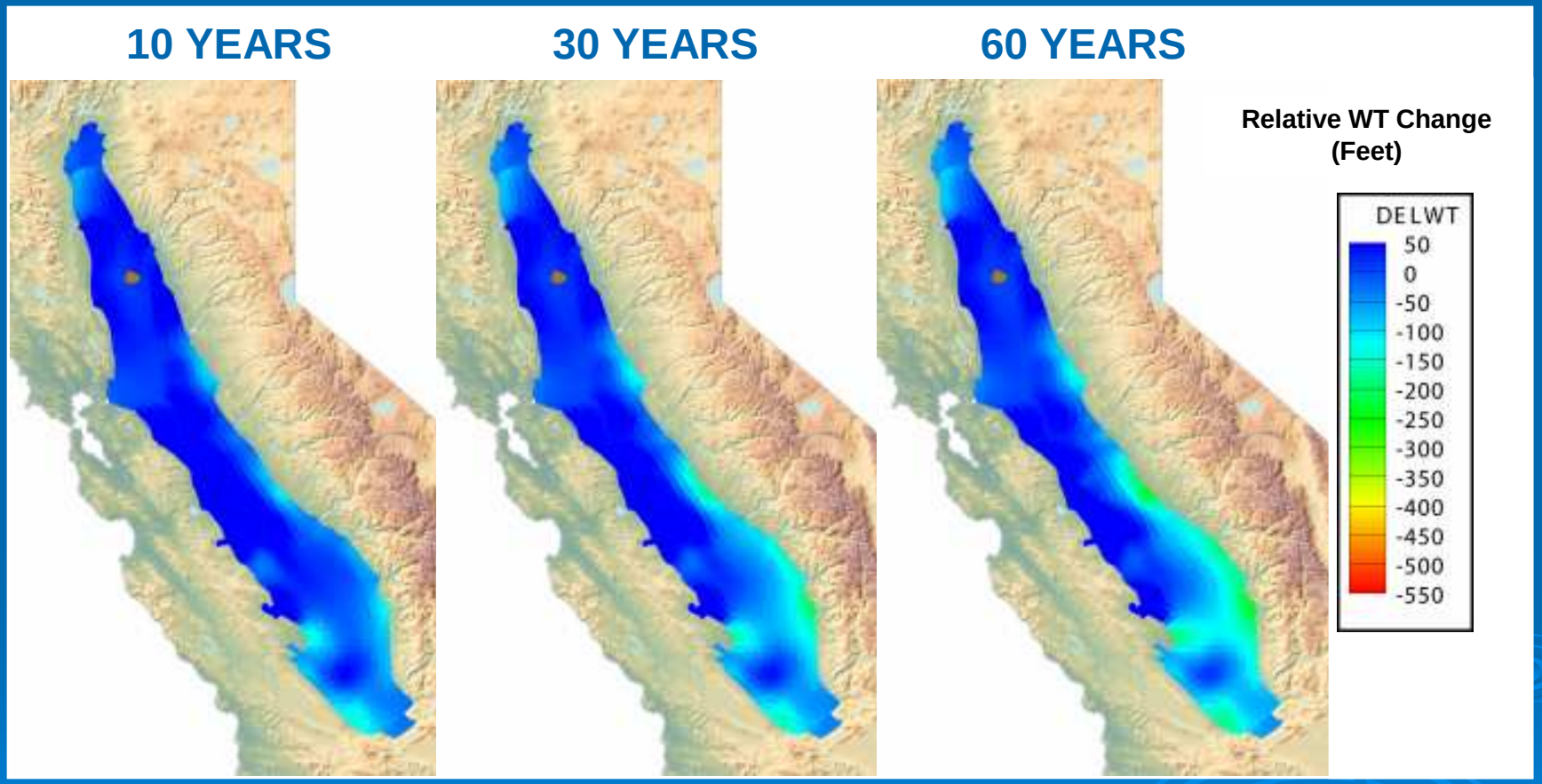
- Simulate 30%, 50% and 70% reduction for 10, 20, 30 and 60 years
  - October 2003 as initial condition
  - 10-yr run-up, drought period, 10-yr recovery
- Climate model results to Calsim for rim inflows
  - Prepare C2VSIM inflow & diversion files
- C2VSIM runs
  1. Turn on groundwater adjustment
  2. Post-process results

"Drought Resilience Of The California Central Valley Surface-Groundwater-Conveyance System" by N. L. Miller et al. Submitted to J. Am. Water Res. Assoc. April 2008.

Central Valley Water Table 'Relative' Response

Joint LBNL-DWR Drought Simulation

30-percent reduction in surface water inflows

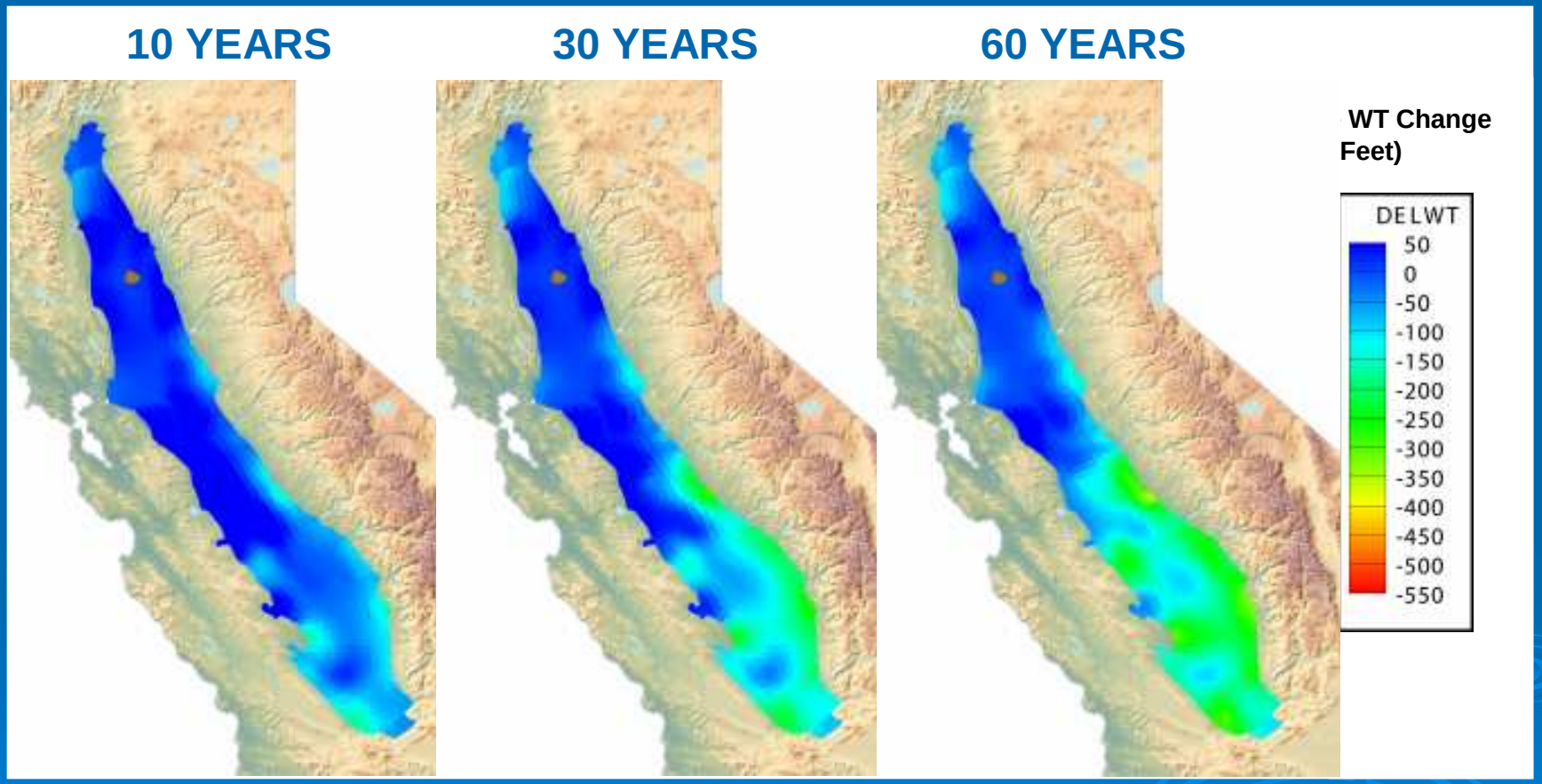


"Drought Resilience Of The California Central Valley Surface-Groundwater-Conveyance System" by N. L. Miller et al. Submitted to J. Am. Water Res. Assoc. April 2008.

Central Valley Water Table 'Relative' Response

Joint LBNL-DWR Drought Simulation

70-percent reduction in surface water inflows



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Summary

- C2VSIM model performs well
  - Regional parameters provide good results
  - Lots of information – areal recharge, storage, GW-SW
  - Groundwater pumping estimates look reasonable
  - Subregional ‘virtual farms’ limit spatial resolution
- Model improvements
  - Need to refine parameters for Kern County
  - Further spatial refinement of parameters (pilot points)
  - Increase calibration data set (observations)
    - especially vertical head gradients and stream-groundwater flow
  - Review selected water budget components:
    - Aquifer storage and recovery programs (direct recharge & pumping)
    - Groundwater exports
    - High wet-season diversions (refuges?)
    - Check crop ET values
    - Verify simulated runoff